TRANSACTIONS

of the

American Society for Steel Treating

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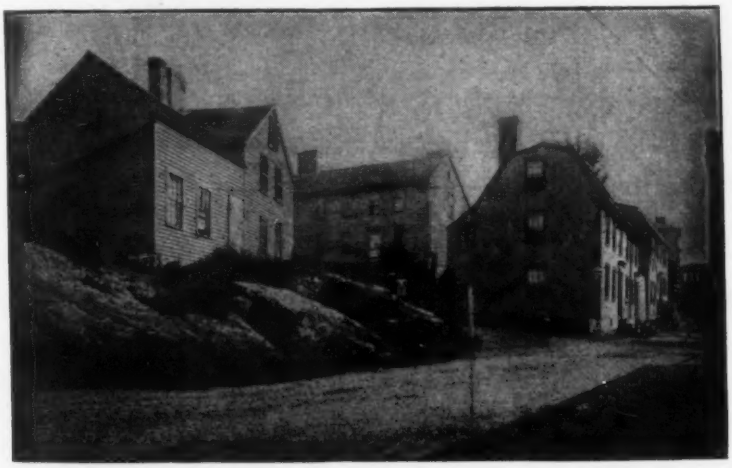
HISTORICAL NEW ENGLAND

The North Shore

THE NORTH SHORE extends from the limits of the city of Boston at Winthrop to Cape Ann. Lynn, about twelve miles distant from Boston, is a great shoe manufacturing city and a point of approach to Nahant, the oldest of eastern summer resorts, occupying a rocky promontory projecting out into Massa-



Street in Quaint Old Marblehead

chusetts Bay. On the extreme point is the summer home of Henry Cabot Lodge. From Lynn, Salem may be reached by way of Swampscott and Marblehead. This is a pleasant route passing many summer homes and traversing the Lynn Shore Reservation which, at its northern end, joins King's Beach in Swampscott.

Passing Beach Bluff and Clifton Heights, Marblehead, the

quaint, irregular town with crooked streets full of old-time suggestions, may be visited.

Marblehead is famous as a rendezvous for yachtsmen. At Marblehead Neck, the Eastern and the Corinthian Yacht Clubs have accommodations for their members. The Boston Yacht Club has its establishment on the town side of the harbor. The features of

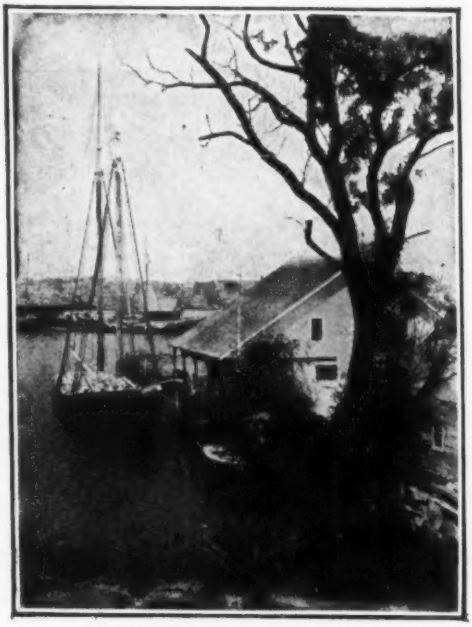
Old Powder House
Marblehead

Marblehead include the old town hall; St. Michael's, the oldest Episcopal church now standing in New England; the old "Floyd Ireson" House; the home and tomb of General John Glover, whose statue is in Boston; and the birthplace of Elbridge Gerry, a signer of the Declaration of Independence. During the World War hydroplanes, manufactured at the Curtiss plant in Marblehead, were tried out in the harbor.

Salem

Salem, once the chief port of New England, was settled in 1626. From Salem came John Winthrop and his companions to the founding of Boston. Here are many stately old houses including the Custom House, in which Hawkridge was employed; the County Jail and Court House, in which many relics of the witchcraft persecution are preserved; Gallows Hill, where the condemned were hung; the house on Federal Street in which

Lafayette was entertained in 1784 and Washington in 1789; Hawthorne's birthplace on Union Street and various Hawthorne homes and landmarks; and the Pickering mansion, built in 1649. Here also are the Essex Institute and the Peabody Academy of Science, with their interesting collections of documents, relics, and curiosities, many of them redolent of the sea and foreign commerce. The oldest house now standing in Salem is at the corner of Essex



Scene at Gloucester

and North streets, and is known as the Witch House, so called persistently without warrant beyond the tradition that some of the preliminary examinations of accused persons were held here, it being at the time of the delusion the dwelling of Judge Jonathan Corwin of the Court. It is said to have earlier been the home of Roger Williams (in 1635-1636).

Beverly, settled in 1628, is now a shoe manufacturing town in one part and a summer resort in other parts. There are many elaborate estates, wooded parks and drives, here and in Pride's Crossing, Beverly Farms, West Manchester, Manchester-by-the-Sea, and Magnolia.

Gloucester

Beyond, nestling under the protection of Eastern Point, is Gloucester, which was settled in 1623. It was and still is a city

of far-voyaging schooners, of seines and nets and fishing lines, of herring and halibut, cod and mackerel; a city whose prosperity is the spoil her rugged sons wrest from the sea with which they battle; a city of orphans and widows, and of wives and children whose hearts are always fearful lest the ship shall come back with the flag at half-mast. But there is another Gloucester—a city of trolleys and telephones and incandescents, of paved streets and tenements, modern enough to have a foreign population, and in

Norman's Woe

summer, a great colony of cottagers. The old Gloucester is by no means gone, for it is the second largest fishing port in the world and here everything savors of the sea. The wealth of the city is founded on the labors of the men "who go down to the sea in ships" and through many hardships, they wrest from it their livelihood. Every year some lives are lost. No memorial day is more impressive than Gloucester's midsummer ceremonial, when her children cast flowers for the dead upon the receding tides of the harbor. It is still a city of sorrow, whose history, some one has said, is written in tears.

Yet while Gloucester is still a fishing city, it is not the city of old. Science and invention have come to the aid of the fisherman. Chemistry uses the wastes of his business. Machinery is doing what labor once did. The market for the fish is certain, for large quantities are dried and canned to be shipped to all parts of the world. There are spar, seine and sail makers' shops, also those which deal in oil, clothing and outfits for fishermen.

In Gloucester was founded the first Universalist church in the

world, and the original building, erected in 1807, is still standing.

At Bass Rocks one has a grand view of the Atlantic Ocean. To the east are the "twin lights" of Thatcher's Island, and along the shore, Little Good Harbor, Long Beach, and Land's End, Rockport. Then may be seen Half Moon Beach, Fort Square, Harbor Beach and Norman's Woe, which is a dangerous reef near the entrance to Gloucester Harbor. Longfellow has celebrated it in his poem "The Wreck of the Hesperus."

"It was the schooner Hesperus,
That sailed the wintry sea;
And the skipper had taken his little daughter,
To bear him company.

* * * * * * * * * * *

"And fast through the midnight dark and drear,
Through the whistling sleet and snow,
Like a sheeted ghost, the vessel swept
Tow'rds the reef of Norman's Woe.

"And ever the fitful gusts between
A sound came from the land;
It was the sound of the trampling surf
On the rocks and the hard sea-sand.

* * * * * * * * * * *

"She struck where the white and fleecy waves
Looked soft as carded wool,
But the cruel rocks, they gored her side
Like the horns of an angry bull.

"Her rattling shrouds, all sheathed in ice,
With the masts went by the board;
Like a vessel of glass, she stove and sank,
Ho! ho! the breakers roared!

* * * * * * * * * * *

"Such was the wreck of the Hesperus,
In the midnight and the snow!
Christ save us all from a death like this,
On the reef of Norman's Woe!"

LIST OF EXHIBITORS—SIXTH ANNUAL EXPOSITION AND CONVENTION, BOSTON

THE following is the official list, at the time of going to press, of those companies and individuals who will exhibit their products at the Sixth Annual Convention and International Steel Exposition of the A. S. S. T., Commonwealth Pier, September 22 to 26, 1924.

ABRASIVE MACHINE TOOL CO. ..... East Providence, R. I.
ACME MACHINE TOOL CO. ..... Cincinnati
ADAMS AND DURKEE STEEL CO., INC. ..... Boston
AIR REDUCTION SALES CO. ..... New York City
ALLEN CO., CHARLES G. ..... Barre, Mass.
AMERICAN GAS FURNACE CO. ..... Elizabeth, N. J.
AMERICAN MACHINIST ..... New York City
AMERICAN METALLURGICAL CORPORATION ..... Boston
AMERICAN STAINLESS STEEL CO. ..... Pittsburgh
AMERICAN TOOL WORKS ..... Cincinnati
AMERICAN TWIST DRILL AND TOOL CO. ..... Detroit
ANDRESEN AND ASSOCIATES, F. C. ..... Pittsburgh
ARMSTRONG-BLUM MANUFACTURING CO. ..... Chicago
ARMSTRONG CORK AND INSULATION CO. ..... Pittsburgh
ATKINS AND CO., INC., E. C. ..... Indianapolis
ATLAS STEEL CO. ..... Dunkirk, N. Y.
AVEY DRILLING MACHINE CO. ..... Cincinnati
BAKER BROTHERS ..... Toledo, Ohio
BARBER COLMAN CO. ..... Rockford
BATH AND CO., INC., JOHN ..... Worcester, Mass.
BAUSCH AND LOMB OPTICAL CO. ..... Rochester, N. Y.
BAY STATE TAP AND DIE CO. ..... Mansfield, Mass.
BELLEVUE INDUSTRIAL FURNACE CO. ..... Detroit
BELLIS HEAT TREATING CO. ..... New Haven, Conn.
BETHLEHEM STEEL CO. ..... Bethlehem, Pa.
BLAKESLEE CO., G. S. ..... Cambridge, Mass.
BLANCHARD MACHINE CO. ..... Cambridge, Mass.
BRISTOL CO. ..... Waterbury, Conn.
BROWN LYNCH SCOTT CO. ..... Monmouth, Ill.
BROWN INSTRUMENT CO. ..... Philadelphia
BROWN AND SHARPE MANUFACTURING CO. ..... Providence, R. I.
BUREAU OF STANDARDS ..... Washington, D. C.
CALORIZING CO. ..... Pittsburg
CAMPBELL CO., INC., A. C. ..... Bridgeport, Conn.
CARBORUNDUM CO. ..... Perth Amboy, N. J.
CARPENTER STEEL CO. ..... Reading, Pa.
CASE HARDENING SERVICE CO. ..... Cleveland
CELITE PRODUCTS CO. ..... Chicago
CENTRAL STEEL CO. ..... Massillon, Ohio
CINCINNATI BICKFORD MACHINE CO. ..... Cincinnati
CINCINNATI GRINDER CO. ..... Cincinnati
CINCINNATI MILLING MACHINE CO. ..... Cincinnati
CINCINNATI PLANER CO. ..... Cincinnati
CLEVELAND TWIST DRILL CO. ..... Cleveland
COCHRAN-BLY CO. ..... Rochester, N. Y.
COLONIAL STEEL CO. ..... Pittsburgh
COMBUSTION UTILITIES CORPORATION ..... New York City
COOPER-HEWITT CO. ..... Hoboken, N. J.
CRESCENT WASHING MACHINE CO. ..... New Rochelle, N. Y.

CRUCIBLE STEEL COMPANY OF AMERICA.....New York City
DAVISON GAS BURNER AND WELDING CO., N. C.....Pittsburgh
DEARBORN CHEMICAL CO.....Chicago
DISSTON AND SONS, INC., HENRY.....Philadelphia
DRIVER-HARRIS CO.....Harrison, N. J.
DYCAST STEEL CO.....Collinsville, Conn.
EATON ELECTRIC FURNACE CO.....Taunton, Mass.
ELECTRO-ALLOYS CO.....Elyria, Ohio
ENGELHARD, INC., CHARLES.....New York City
FEDERAL MACHINE AND WELDER CO.....Warren, Ohio
FIRTH-STERLING STEEL CO.....McKeesport, Pa.
FITCHBURG MACHINE WORKS.....Fitchburg, Mass.
FORD CO., J. B.....Wyandotte, Mich.
FORGING—STAMPING—HEAT TREATING.....Pittsburgh
GANSCHOW CO., WM.....Chicago
GENERAL ALLOYS CO.....Boston
GENERAL ELECTRIC CO.....Schenectady, N. Y.
GENERAL FURNACE CO.....Philadelphia
GENERAL WELDING AND EQUIPMENT CO.....Boston
GEOMETRIC TOOL CO.....New Haven, Conn.
GODDARD AND GODDARD CO.....Detroit
GOSS AND DeLEEUW MACHINE CO.....New Britain, Conn.
GOULD AND EBERHARD, INC.....Newark, N. J.
HAGAN CO., GEORGE J.....Pittsburgh
HALCOMB STEEL CO.....Syracuse, N. Y.
HAUCK MANUFACTURING CO.....Brooklyn, N. Y.
HAYES, C. I.....Providence, R. I.
HEALD MACHINE CO.....Worcester, Mass.
HEIM GRINDER CO.....Danbury, Conn.
HENDEY MACHINE CO.....Torrington, Conn.
HEPPENSTALL FORGE AND KNIFE CO.....Pittsburgh
HIGH SPEED HAMMER CO.....Rochester, N. Y
HOSKINS MANUFACTURING CO.....Detroit
HOUGHTON AND CO., E. F.....Philadelphia
HUNT STEEL CO., A. E.....Boston
HUNTER SAW AND MACHINE CO.....Pittsburgh
ILLINGWORTH STEEL CO., JOHN.....Philadelphia
INDUSTRIAL GAS EQUIPMENT CO.....New Haven, Conn.
INTERNATIONAL NICKEL CO.....New York City
IRON AGE PUBLISHING CO.....New York City
JESSOP AND SONS, INC., WM.....Boston
JONES AND LAMSON MACHINE CO.....Springfield, Vt.
JONES AND LAUGHLIN STEEL CORPORATION.....Pittsburgh
KARDEX COMPANY.....Tonawanda, N. Y.
KELLER MECHANICAL ENGINEERING CORPORATION.....Brooklyn, N. Y.
KEYSTONE LUBRICATING CO.....Philadelphia
KING REFRACTORIES CO., INC.....Buffalo, N. Y.
LEEDS AND NORTHRUP CO.....Philadelphia
LEITZ, INC., E.....New York City
LEWIS-SHEPARD CO.....Boston
LODGE AND SHIPLEY MACHINE TOOL CO.....Cincinnati
LUDLUM STEEL CO.....Watervliet, N. Y.
LYND-FARQUHAR CO.....Boston
McDONALD AND CO., P. F.....Boston
MIDVALE CO.....Nicetown, Philadelphia
MOLINE TOOL CO.....Moline, Ill.
MONARCH MACHINE TOOL CO.....Sydney, Ohio
NATIONAL AUTOMATIC TOOL CO.....Richmond, Ind.

NATIONAL ELECTRIC LIGHT ASSOCIATION.....Boston
NATIONAL TWIST DRILL AND TOOL CO.....Detroit
NEW BRITAIN MACHINE CO.....New Britain, Conn.
NEW ENGLAND ASSOCIATION OF GAS ENGINEERS.....Boston
NEW ENGLAND TOOL AND ANNEALING CO.....S. Boston
NORTON CO.....Worcester, Mass.
NUTTALL CO., R. D.....Pittsburgh
OHIO MACHINE TOOL CO.....Kenton, Ohio
OHIO STEEL FOUNDRY CO.....Springfield, Ohio
OLSEN TESTING MACHINE CO., TINIUS.....Philadelphia
OXWELD ACETYLENE CO.....New York City
PANGBORN CORPORATION.....Hagerstown, Md.
PEERLESS MACHINE CO.....Racine, Wis.
PENNSYLVANIA PUMP AND COMPRESSOR CO.....Easton, Pa.
PENTON PUBLISHING CO.....Cleveland
PITTSBURGH CRUCIBLE STEEL CO.....Pittsburgh
POTTER AND JOHNSON MACHINE CO.....Pawtucket, R. I.
PRATT AND WHITNEY.....Hartford
PRENTISS CO., HENRY.....Boston
RACINE TOOL AND MACHINE CO.....Racine, Wis.
REPUBLIC FLOW METERS CO.....Chicago
RIVETT LATHE AND GRINDER CORPORATION.....Boston
ROCKFORD MILLING MACHINE CO.....Rockford
ROCKWELL CO., W. S.....New York City
RODMAN CHEMICAL CO.....Verona, Pa.
ROESSLER AND HASSLACHER CHEMICAL CO.....New York City
RYAN AND CO., F. J.....Philadelphia
SENECA FALLS MACHINE CO.....Seneca Falls, N. Y.
SHORE INSTRUMENT AND MANUFACTURING CO.....Jamaica, N. Y.
SIMONDS SAW AND STEEL CO.....Fitchburg, Mass.
SPENCER TURBINE CO.....Hartford, Conn.
SLY MANUFACTURING CO., W. W.....Cleveland
STEEL CITY TESTING LABORATORY.....Detroit
STROMBERG ELECTRIC CO.....Chicago
SURFACE COMBUSTION CO.....New York City
SWEDISH CRUCIBLE STEEL CO.....Detroit
TACONY STEEL CO.....Philadelphia
THOMSON ELECTRIC WELDING CO.....Lynn, Mass.
THOMPSON CO., HENRY G.....New Haven, Conn.
UNITED ALLOY STEEL CORPORATION.....Canton, Ohio
UNION TWIST DRILL CO.....Athol, Mass.
V. AND O. PRESS CO.....Hudson, N. Y.
VANADIUM-ALLOYS STEEL CO.....Latrobe, Pa.
VANADIUM CORPORATION OF AMERICA.....New York City
VULCAN CRUCIBLE STEEL CO.....Aliquippa, Pa.
WALCOTT LATHE CO.....Jackson, Mich.
WALKER CO., O. S.....Worcester, Mass.
WALLACE AND SONS MANUFACTURING CO., R.....Wallingford, Conn.
WARD'S SONS CO., EDGAR T.....Boston
WARNER AND SWASEY CO.....Cleveland
WESTINGHOUSE ELECTRIC AND MANUFACTURING CO.....East Pittsburgh
WETHERELL BROTHERS CO.....Cambridge, Mass.
WHEELOCK LOVEJOY AND CO., INC.....Cambridge, Mass.
WHITEHEAD METAL PRODUCTS CO.....New York City
WHITMAN AND BARNES MANUFACTURING CO.....Akron, Ohio
WILMARTH-MARMON CO.....Grand Rapids, Mich.
WILSON-MAEULEN CO.....New York City
WOLFF GAS RADIATOR CO., A. H.....New York City

HOTEL ACCOMMODATIONS FOR THE BOSTON CONVENTION

FOR the third time we are publishing the list of hotels in order to give those who are planning on attending the Convention, an opportunity to make selections in obtaining their hotel reservations in case they have not already done so. The Copley Plaza Hotel will be the headquarters of the Society, and we have been advised that this hotel is unable to take care of any more reservations for

Copley Plaza
(Convention Headquarters)

the week of the Convention, consequently, it will be necessary for those who have not already made their reservations to select some hotel other than the Copley Plaza.

In making reservations members are requested to write directly to the manager of the hotel at which he wishes to be located, stating time of arrival, kind of accommodations desired and price he wishes to pay. It is also necessary that hotel management be requested to acknowledge receipt of each reservation.

It will be noted that the hotels are listed according to their nearness to Copley Square, the site of the Copley Plaza. The final tabulation gives the distances of each hotel from the Copley Plaza, as well as from Commonwealth Pier, where the exposition will be held.

List of Boston Hotels*

(Listed in order of nearness to Copley Square)

Copley Plaza

1 person, with bath, inside	$ 5.00 to $ 6.00
1 person, with bath, outside	8.00 to 10.00
2 persons, with bath, inside	8.00
2 persons, with bath, outside	11.00 to 15.00

Westminster

1 person, with bath	3.50
2 persons, with bath	6.00 to 7.00
4 persons, with bath, suites	12.00

Brunswick

1 person, without bath, with running water	2.50 to 3.50
1 person, with bath	4.00 to 5.00
2 persons, without bath, with running water	5.00
2 persons, with bath	6.00 to 8.00
4 persons, with bath, suites per person	3.00

Lenox

1 person, without bath, with running water	3.00 to 3.50
1 person, with bath	4.00 to 6.00
2 persons, without bath, with running water	4.00 to 5.00
2 persons, with bath	5.00 to 8.00
4 persons, with bath, suites	12.00

Vendome

European Plan

1 person, with bath	3.50 and up
1 person, with bath, sitting room chamber	5.00 and up
2 persons, with bath	5.00 and up
2 persons, with bath, sitting room chamber	7.00 and up

American Plan

1 person, with bath	7.00 and up
2 persons, with bath	13.00 and up
1 person, with bath, sitting room chamber	11.00 to 16.00
2 persons, with bath, sitting room chamber	15.00 to 20.00

Arlington

1 person, with bath	3.00
2 persons, with bath	4.00

Touraine

1 person, with bath	5.50 to 7.50
2 persons, with bath	8.00 to 10.50

Adams House

1 person, without bath	2.50 to 3.50
1 person, with bath	4.50 to 6.00
2 persons, without bath	4.00 to 5.50
2 persons, with bath	6.50 to 10.00

*All European plan except as otherwise stated.

Somerset

1 person, without bath	4.00	
1 person, with bath	5.00 to	7.00
2 persons, without bath	5.00	
2 persons, with bath	6.00 to	8.00
4 persons, with bath	10.00 to	12.00

Avery

2 persons, with bath	5.50 to	6.50

Parker House

1 person, without bath	2.50 to	3.50
1 person, with bath	3.50 to	6.00
2 persons, without bath	4.00 to	5.50
2 persons, with bath	5.50 to	8.50

Bellevue

2 persons, without bath	5.00 to	6.00
2 persons, with bath	8.00 to	12.00

Young's Hotel

1 person, without bath	1.75 and up
1 person, with bath	3.50 and up
2 persons, without bath	4.00 and up
2 persons, with bath	6.00 and up

Essex

1 person, without bath	2.50 to	3.50
1 person, with bath	3.50 to	5.00
2 persons, without bath	4.00 to	5.00
2 persons, with bath	6.50 to	8.00

United States Hotel

1 person, without bath, with running water	2.00 to	2.50
2 persons, without bath, with running water	4.00 to	4.50
1 person, with bath	3.00 to	4.00
2 persons, with bath	5.00 to	6.00
2 persons, with bath, suites	6.50	
3 persons, with bath, suites	7.75	
4 persons, with bath, suites	9.00	

Commonwealth

2 persons, without bath	4.50
2 persons, with bath	5.50

Boston Tavern

1 person, without bath	2.00 to	2.50
2 persons, without bath	3.50	
2 persons, with bath	5.00	

Healy's

1 person, without bath	3.00	
1 person, with bath	3.50	
2 persons, without bath	4.50 to	5.00
2 persons, with bath	5.00 to	6.00

AMERICAN HOUSE

1 person, with bath, with running water.....	2.25	to	2.50
2 persons, without bath, with running water...	4.00		
4 persons, without bath, with running water...	5.50	to	6.50
2 persons, with bath.....	5.00	to	6.00
2 persons, with bath, suites.....	8.00		

QUINCY HOUSE

1 person, without bath.....	2.00		
1 person, without bath, with running water....	2.50		
1 person, with bath	3.00	to	4.00
2 persons, without bath, with running water...	4.00		
2 persons, with bath.....	5.00	to	7.00

List of Hotels Showing Their Location in Respect to Copley Square and Commonwealth Pier

Hotel	*Number Rooms*	*Distance from Headquarters. Miles*	*Distance from Exposition. Miles*	*Address*
Copley-Plaza 500		0.0	2.25	Copley Square
Westminster 250		0.0	2.25	Copley Square
Brunswick 275		0.25	2.25	Boylston & Clarendon Sts.
Lenox 200		0.25	2.25	Exeter St.
Vendome 250		0.25	2.25	Commonwealth Ave.
Arlington 300		0.50	1.5	Arlington Sq. & Chandler St.
Touraine 225		0.75	1.75	Tremont & Boylston Sts.
Adams House ...460		0.75	1.75	555 Washington St.
Somerset 300		0.75	3.00	Commonwealth Ave.
Avery 150		0.75	1.75	Washington & Avery Sts.
Parker House ...321		1.00	1.25	Tremont & School Sts.
Bellevue 250		0.75	1.5	Beacon Hill
Young's 200		1.00	1.25	Court & City Hall Sts.
Essex 300		1.00	0.75	Atlantic Ave. & Essex St.
United States ...250		1.00	1.00	Essex St.
Commonwealth ...210		1.00	1.00	Bowdoin St., Beacon Hill
Boston Tavern ...125		1.00	1.25	347 Washington St.
Healy's 75		0.75	1.75	642 Washington St.
American House..275		1.25	1.5	56 Hanover St.
Quincy House ...500		1.25	1.5	Brattle St.

THE SIXTH ANNUAL EXPOSITION AND CONVENTION

EVERY year shows a remarkable increase in the activities of the A. S. S. T. The International Exposition and Convention in Boston will be no exception. The program that has been prepared represents an unusually strong feature that will prove attractive,

not only to members of the A. S. S. T., but to many others interested in metal treating and metal working.

The Exposition this year will be the largest ever held under the auspices of the Society, being 30 per cent larger than at Pittsburgh last year, which up to that time marked the high water point of A. S. S. T. Convention's activities. Last year 79,000 square feet were used, while this year 150,000 square feet will be necessary to accommodate all those exhibitors desirous of showing their products. Your attention is called to the list of exhibitors on pages 116, 117 and 118.

The Boston Committees under the able direction of General Chairman A. O. Fulton have been working incessantly and tirelessly in the preparation for the various events which mean so much to a successful convention.

The hotels of Boston are rapidly filling up with reservations, although there are yet a large number of accommodations available. The hotels have expressed a wish that wherever possible group reservations be made, inasmuch as a great many of the rooms available at present are adjoining rooms with connecting bath. There is no doubt, whatever, that the fine hotel facilities in Boston will be adequate to take care of the 7,000 visitors from out of town. In case, however, you encounter difficulty in securing proper hotel reservations, a communication addressed to A. Hartel, Jr., 307 Atlantic Ave., Boston, will solve your problem.

The Ladies' Entertainment Committee has made preparations for the reception of about 400 ladies. This is a much larger number than has attended previous conventions, but Boston has a particular lure for the ladies, and the local Committee is more than anxious that when the ladies depart they will carry with them pleasant remembrances of New England hospitality.

SELFISHNESS

IT is maintained that selfishness is a characteristic human trait, and that the great majority of people are always intently considerate of their own important ends; and in case an opportunity is afforded for service, the natural tendency is to observe this possibility of service in the light of its reactionary effect upon one's self.

While this may be an American ego for a few, we are loath to

believe it is a national characteristic. We are rather confident it is not characteristic of the members of the A. S. S. T. The very principle upon which the organization was founded, that of service one to another, has been the stepping-stone from a humble beginning to national prominence and success. When one takes into consideration the large number of members who give unsparingly of their valuable time and special qualifications to the preparation of papers for presentation before the Society; when one recalls the many who participate in the discussions, symposia and round tables, each contributing his experiences to the particular subjects under consideration, one comes firmly to the conviction that selfishness has no place in an A. S. S. T. man's make up, but that they are all impelled forward and upward by the constantly recurring opportunities for helpfulness.

Besides the many opportunities afforded in the Society for unselfish activities, there is one that should at this time be frequently presenting itself to your thoughts. Your Society has prepared a full five days of interesting activities to take place at the Annual Convention and Exposition in Boston the week of September 22nd. The many important papers and discussions to be presented at that time contain wonderful possibilities for being of exceptional service to many others than members of the Society. The International Steel Exposition with its 200 exhibitors occupying 150,000 square feet of beautiful Commonwealth Pier, with over a million dollars of equipment, the greater portion of it in operation, offers an unusual opportunity to many thousands of interested individuals to observe, compare and study the latest products and equipment in the metal working and metal treating industries.

This educational convention and exposition presents to the members of the A. S. S. T. a remarkable occasion to demonstrate their unselfishness to the highest degree. All of the members of the A. S. S. T. should feel it a duty to extend an invitation to participate, to all who would in any way be interested in obtaining benefits from the activities of the Society at the coming convention and exposition. Not only that, but after your friends and guests arrive at Boston, let it be a part of your duty as a member of the Society to extend to all visitors cordial greetings and let them feel the welcome of the A. S. S. T.

PROGRESS IN THE MANUFACTURE AND USE OF CLAY REFRACTORIES

By W. G. Owen

Abstract

Better clay refractories are resulting from greater knowledge of materials and improved processes of manufacture. Acceptable machine-made brick are being produced. Brick will soon be classified according to their service requirements. Every brick is a first quality brick for the particular service for which it is suitable. Life of brick greatly depends upon the care exercised in building them into furnaces and the quality of the mortar used in laying them up. Not any one grade of brick will give most efficient results in all places. The service encountered should determine the characteristics of the brick used. The heat treater's refractory problems should be few at the temperatures which he usually does his work. A great number of satisfactory brick for heat treating furnaces are available throughout this country.

Period of Growth and Development

SIMILAR to the growth and development of industry as a whole during the last ten years has been the progress of the refractories industry. In order to support this statement, a brief resumé will follow which will include the most important contributions made to this industry.

By supporting a refractories fellowship in Mellon Institute of Industrial Research, and refractories divisions in the American Ceramic Society and American Society for Testing materials, in addition to research departments in some of their own organizations, much valuable knowledge has been acquired relative to both the raw and finished materials.

Acknowledgment is also made of the excellent ceramic work which has been executed in the laboratories of the steel industry,

A paper to be presented before the Sixth Annual Convention of the Society to be held in Boston, September 22 to 26, 1924. The author, W. G. Owen, is assistant manager of sales with the Haws Refractories Co., Johnstown, Pa. Written discussion is invited.

the non-ferrous industries and by the Bureau of Mines and the Bureau of Standards of our Government.

The past ten years has seen the development of better machinery and equipment especially for the manufacture of clay brick. Modern machinery for the sizing, proportioning, mixing, shaping and conveying of the materials has been realized; also more efficient driers and kilns. Other types of machines, driers and tunnel kilns, designed to further revolutionize the industry, are in process of development. Some of this machinery was supplied to meet a labor shortage, resulting from our participation in the World War.

A number of processes of making brick by machinery were resorted to during this period, among them being the auger, pug and auger, power press, steam press, dry press and various combinations of these processes.

Manufacture of Brick by Machinery

The quality, or merit, of the product from the numerous machine methods of making brick depends greatly on the character of the clays used and the manner in which the clays are sized, proportioned, ground, or worked, extruded and pressed. It is a known fact that some processes are to be preferred to others.

The war period ushered in a more general use of machine-made brick on a quantity basis, and thus afforded an opportunity to demonstrate to the trade that a good machine-made brick would give satisfactory service in most places where previously only hand-made brick were acceptable. The acceptability of machine-made brick has continued and from the increased demand, there is no question but what they are here to stay.

There are certain services that require an open-structure, or coarse ground, hand-made non-spalling brick, but these requirements are very small compared with the total consumption of clay fire brick.

Some consumers are prejudiced against the use of any machine-made brick, regardless of the service. Cooperation between consumer and producer will best determine the correct brick for the service for which they are intended.

Some of the advantages of machine-made brick are:—

a—Burns being equal will sustain greater load under temperature

b—Being stronger and denser will be more resistant to abrasion

c—Greater resistance to slagging on account of its density

d—Contains more clay to resist solution

e—There is more clay; therefore, more thermal capacity

f—Truer to size and shape

g—Will lay up with less mortar

h—Less resistant to sudden temperature change or the action of spalling.

Refinements are continually being made in the present processes for the purpose of overcoming the primary objection held by the consumers against the machine-made product; viz., its inability to equally resist the action of sudden temperature change, or spalling, with the more porous hand-made brick.

Some encouragement in this direction is expected from the recent use and development of the dry press process of manufacture. While this method has been in use for years in the manufacture of second and third quality brick, yet its successful application to first quality brick is more recent. Clays suitable for manufacture by this method will yield a product that will closely approach a hand-made brick even as it pertains to resistance to sudden temperature change.

Demands of Trade for Better Refractories

The trade is demanding greater uniformity, especially in the thickness of brick, and progress can be reported in this direction.

Some producers have adopted one or the other method of planing the green brick to attain uniformity in thickness. The industry in general is studying the shrinkages of their raw clays, the moisture content of the mixes, and the grog additions to the mixes, with the expectancy of gaining the same end.

The statement is sometimes made that present refractories are of a poorer quality than those produced in past years. If present

refractories fail more rapidly than those of other years, it is more likely due to higher operating temperatures prevailing because of desire for increased furnace capacity.

It is quite apparent from statements made at conventions of steel and non-ferrous societies that it is believed that refractories are an important hindrance in the development of certain more efficient furnaces, or processes, in their respective industries. Some believe that progress can only be made by the discovery of new materials, natural or synthetic. However, for the majority of services the present refractory materials are quite adequate and greatest relief will probably come as the result of changes in modes of manufacture, which include closer control of the various factors involved in the production of the brick. This may entail slower production, which will be reflected in the costs to the producer and the consumer alike. The trade must come to appreciate that the first cost per thousand of the brick is not as important a figure as the cost of the brick per ton of product produced.

Assuming that better refractories can be made from natural materials now available, yet to obtain more excellent service results, there must of necessity be closer cooperation between the consumer and the producer.

Following are several things of which the user should be mindful and actually practice to obtain best results:

a—Give due consideration to furnace design
b—Use least number of difficult irregular shapes
c—Care in unloading and storing.
d—Good masonry workmanship in building brickwork
e—Reasonable control of furnace operation
f—Records of behavior and life of brick in service.

Further, they can assist in calling producers' representatives into conferences on brick problems or troubles. Just a few years ago it was practically impossible for a producer to get within the confines of an industrial plant, but, fortunately, this day is rapidly passing. Those who have thrown open their doors to the refractory engineer or ceramist have profited most. The consumer can also render a mutual service by specifying on his inquiry or order, as far as possible, the use for which the brick are being purchased, instead of merely stating first, second or third quality.

Need of Specifications

The consuming trade feel, and justly so, that there should be some simple yet comprehensive specifications for the purchase of brick. The refractories industry has keenly appreciated this need and has labored diligently to attain the same. Quite likely the reason specifications have not been perfected long since is apparently a lack of faith in each other between consumer and producer. The former has possibly felt that if the latter prepared the specifications they would only be rigid enough to cover average grades of commercial brick, and the producer has likely been convinced that the consumer is not in possession of sufficient reliable data from which to prepare reasonable specifications. It is obvious that each user and maker of brick cannot write his own individual specifications. Evidently a third, or disinterested, party must assist. In fact, this is just what is now being done. A group, consisting of representatives from among the consumers and producers and the Bureau of Standards, has undertaken such a task.

Some constructive work on specifications for stoker-fired boiler settings has been performed, boiler service having been the first selected. This work was inaugurated by the Bureau of Standards for use in the purchase of materials for their various departments, but also with the thought that the same might ultimately be adopted by the trade.

Manifestly, such work is extremely slow since many tests must be made to establish the values necessary as a basis for the specifications. Likely much of the data acquired can be used for brick in other services.

As previously stated, the need of suitable specifications and the task involved in the preparation of the same has been given serious consideration by the manufacturer of refractories, particularly in recent years. The men who have devoted much time to this subject have agreed that in order to be of industrial value, specifications must be prepared on a service basis.

Service Classification

The Refractories Committee of the American Society for Testing Materials, which is equally divided between consumers and

producers, undertook to study the feasibility of constructing specifications on a service basis. The work proceeded and from several plans suggested, a tentative plan was determined upon by which refractories could be classified according to their service

SERVICE CLASSIFICATION OF REFRACTORIES

		LOAD UNIMPORTANT			LOAD MODERATE			LOAD IMPORTANT		
		ABRASION UNIMPORTANT	ABRASION MODERATE	ABRASION IMPORTANT	ABRASION UNIMPORTANT	ABRASION MODERATE	ABRASION IMPORTANT	ABRASION UNIMPORTANT	ABRASION MODERATE	ABRASION IMPORTANT
SLAG ACTION UNIMPORTANT	SPALLING UNIMPORTANT	1	2	3	4	5	6	7	8	9
	SPALLING MODERATE	10	11	12	13	14	15	16	17	18
	SPALLING IMPORTANT	19	20	21	22	23	24	25	26	27
SLAG ACTION MODERATE	SPALLING UNIMPORTANT	28	29	30	31	32	33	34	35	36
	SPALLING MODERATE	37	38	39	40	41	42	43	44	45
	SPALLING IMPORTANT	46	47	48	49	50	51	52	53	54
SLAG ACTION IMPORTANT	SPALLING UNIMPORTANT	55	56	57	58	59	60	61	62	63
	SPALLING MODERATE	64	65	66	67	68	69	70	71	72
	SPALLING IMPORTANT	73	74	75	76	77	78	79	80	81

Temperature: Indicated by Prefixing Proper Letter To Number
H = High Temperature
M = Moderate Temperature
L = Low Temperature

Example: M-21 Indicates Moderate Temperature, Unimportant Load, Unimportant Slag Action; Abrasion and Spalling Both Important.

Fig. 1

requirements. The work is reported under Committee C-8, in Volume 23, 1923, covering the proceedings of the A. S. T. M.

The principle upon which the service classification is based is that all refractories may be divided into various classes, depending upon the destructive influences which they are called upon to resist in service. For general industrial service the classification may be based upon the five major variables, or factors, of temperature; load, abrasion, slag action and spalling.

The assumption that each of these conditions may exist in an important, unimportant and moderate degree led to the classification as shown in Fig. 1. Temperature is indicated by prefixing the letters H, M or L to the proper number. A study of this chart will disclose a possible eighty-one types of service. However, for obvious reasons, the committee decided to omit one degree of resistance; viz., the moderate degree, and choose for the present only the sixteen classes of service, which are shown crosshatched on the chart. These classes should be ample for the present. It is quite likely that at least some of the existing standard tests for refractories will have to be revised to fit in with this work.

Over a course of years the American Society for Testing Materials have carefully prepared and adopted a series of standard tests for refractories. Full descriptions of these, which are listed below, can be procured from the Society's office.

Standard Definitions for Clay Refractories, C-27-20.

Standard Methods for Ultimate Chemical Analysis of Refractory Materials, C-18-20.

Standard Test for Porosity and Permanent Volume Changes in Refractory Materials, C-20-20.

Standard Test for Refractory Materials under Load at High Temperature, C-16-20.

Standard Test for Softening Point of Fire Clay Brick, C-24-20.

Tentative Test for Slagging Action of Refractory Materials, C-17-19-T.

Resistance of Fire Clay Brick to Spalling Action, C-38-21-T. (Tentative test.)

In order to make service classification worthwhile, much data relative to the service conditions of furnaces in the various industries must be procured. A branch of this same committee is now, and has been for more than a year, making a survey of certain industries. Cooperation on the part of industry will greatly speed up this long and tedious undertaking. Apparently many consumers fail to appreciate the great importance of this work and treat lightly the requests for data relative to their particular furnaces.

Once service classification is a reality, there will no longer be first, second and third quality brick. Every brick will be a first quality brick for the particular service for which it is best suited. For instance, a one hundred per cent plastic clay ladle brick is a first quality brick for ladle lining and similar services.

Misapplication of Brick

Refractory engineers and representatives find upon visiting industrial plants, that very often the wrong grade of brick is being used in certain parts of their furnaces. Many times a first quality brick is used where a second quality is cheaper and would give longer life and, too, first quality are even used where a third quality or an all plastic clay brick would be preferable. Quite often good quality brick are used, but a poor quality fire clay or mortar is employed in laying them up. Many times good clay is supplied by the manufacturer but it is materially changed by the consumer by the addition of Portland cement, salt, water glass, etc. The mortar must be of as good quality as the brickwork, otherwise good results cannot be expected.

In many services refractoriness and resistance to spalling are not the essential qualifications. Quite often resistance to abrasion and slagging action are most important. There are more than one hundred brands of clay brick, all of which are suitable for numerous services.

Once the requirements of the brick are determined, which will be made easy by the service classification, the manufacturer can more intelligently supply a brick to resist the destroying actions which prevail in furnaces. The manufacturer can produce brick for any service by the selection of materials, proportioning the flint and plastic clays, and by the sizing, mixing, moulding, and burning of the same.

General

For many years, one of the serious problems blast furnace operators have been confronted with, is the disintegration of the clay fire brick in the tops and upper inwalls of their furnaces. Investigators are generally in agreement that this trouble is greatly due to a reaction between the iron oxide in the brick and

the carbon monoxide gas, at certain low or top temperatures. By the selection of clays, which have a minimum iron oxide content, this problem is now being solved. Some producers have even resorted to the use of hard burned silica brick on account of the extremely low iron oxide content.

Some consumers who have been willing to venture into the realm of experiment, even to the extent of discarding best accepted practice and theory, have achieved some gratifying results, especially by the substitution of silica brick for clay brick. On account of the tendency of silica brick to spall at low temperatures and when subjected to sudden temperature change, the use of silica brick has been more or less limited. However, in recent years silica brick have been successfully used in the tops of blast furnaces, zinc oxide furnaces, ingot soaking pits and in the flue arches of certain furnaces where clay brick have given unsatisfactory results.

In addition to more common clay, silica, chrome and magnesite refractories, there are the super-refractories which include zirconia, carborundum, alundum, bauxite, sillimanite and spinel. However, most of these have drawbacks of one kind or another, among which are high cost, great shrinkage, high conductivity, increased weight and tendency to spall or disintegrate.

Space will not permit saying anything regarding the various refractories used in the more common practices of smelting and refining iron and steel.

Heat Treating Furnaces

What has thus far been said has only been of a general interest to the heat treater. Undoubtedly he is more specifically interested in brick for his own particular field.

He is fortunate in being in a field of endeavor in which refractories are not, or at least should not be, a serious problem. This is, of course, primarily due to the lower temperature found in many heat treating processes, compared with those which prevail in the actual manufacture of iron and steel, particularly in the open hearth and electric furnaces. Silica brick in electric furnace roofs are required to withstand temperatures within 100 degrees Cent. of their point of fusion.

Like other industrial furnaces, the success of the numerous types of furnaces used in heat treating operations depends largely on the design of the same. Design necessarily includes proper furnace proportions as to size of combustion chambers, height and rise of arch, correct vent areas, type and location of burners, length of flame travel, correct fuel, insulation, etc.

After trained furnace engineers have correctly designed the furnaces, it follows that the units must be properly and efficiently constructed to give long life and satisfactory results. This is particularly true since the major portion of the units are built of fire brick. Brickwork in heat treating furnaces should fail much more rapidly from defective construction than from the result of the destroying action of the heat and gases. In other words, in heat treating work we have a large factor of safety as far as the chemical and physical qualities of the brick are concerned.

Since there are so many types and sizes of furnaces used in the annealing, hardening, tempering, drawing, carburizing, etc., of steel, it would be quite difficult to specify or recommend any particular kind of clay brick. This is more obvious when it is considered that these furnaces range in size from a muffle furnace 6x12 inches to annealing furnaces 4.5 feet wide to 60 to 90 feet long, and include muffle, semi-muffle, open chamber, lead pot, side-fired and over-fired car type, long continuous, automatic electric, high temperature continuous electric and electric roll heating, and many modifications of these types. One is also dealing with furnaces having temperature ranges of from 325 to 1725 and up to about 2500 degrees Fahr. for high speed tool work. Oil, gas, coal and electric current are used as fuels, with fuel oil in most common use.

Brick for Heat Treating Furnaces

It must be borne in mind that the clay brick on many furnaces are insulated in order to conserve the heat, thus lowering the cost of operation. All of the brick, with the exception of the few carborundum brick used in the burner opening and in the combustion walls opposite, where the flame from the burner impinges, are clay brick.

Data Relative to Refractories

Following is some data relative to the more common refractories:

Chemical Analysis of Brick

Kind	Clay	Silicious Clay	Silica	Carborundum	Magnesite
Silica	50.0–65.0	70.0–85.0	93.0–97.0	..	5.0 to 8.0
Alumina	45.0–30.0	28.0–15.0	0.3– 2.0	up to 2.0	1.0 to 1.5
Iron oxide	2.0– 4.0	0.5– 1.5	0.3– 1.5	up to 1.0	5.0 to 8.0
Lime	0.3– 0.6	0.2– 0.3	1.6– 3.0	up to 0.3	3.0 to 5.0
Magnesia	0.2– 0.5	0.2– 0.3	0.1– 0.4	..	80.0 to 90.0
Alkalies	0.5– 2.0	0.5– 1.5	0.2– 0.6	..	..
Titania	2.0– 2.5	1.0– 2.0	..	..	..
Carbon	..	..	..	27 to 30	..
Silicon	..	..	..	65 to 70	..

Fusion Points and Specific Gravity

	Clay	Silica	Carborundum	Magnesite
			Decomposes at	
Fusion Points	1615 to 1715° C	1700 to 1705° C	2240° C	2165° C
Specific Gravity.	2.55 to 2.80	2.29 to 2.45	3.12–3.20	3.44–3.60

Specific Heats of Brick

	At 100° C	At 1000° C
Firebrick	0.199	0.253
Silica	0.219	0.298
Magnesite	0.231	0.324
Carborundum	0.186 (31–985°)	..

Thermal Conductivity of Brick at 1000 Degrees Cent. (1832 Degrees Fahr.) in Calories Per Centimeter Cube Per Second Per Degree Cent.

Observer	Fireclay	Silica	Magnesia	Carborundum
Dudley	0.0034	0.0042	...	...
Wologdine	0.0042	...	0.0071	0.0231
Dougill, Hodsman Cobb.	0.0040	0.0046	0.0085	...
Goerens and Gillis	...	...	0.0080	...
Average	0.0039	0.0044	0.0079	0.0231

On account of insulating the brickwork, a first quality clay brick of good refractoriness should be used. With the possible exclusion of the brick for the arches and bridge walls, machine-made brick should be just as acceptable as hand-made. Certain machine-made brick, depending upon the process of manufacture and density, could be used throughout the construction. The

producer is in a position to advise on this point. Well made brick with reasonably true surfaces are required to permit accurate laying up with thin joints.

There are produced in many sections of our country a large variety of clay brick which have the requisite qualities for heat treatment work. From experience, the contractor that builds furnaces has learned which grade of brick give best results in the different sections of the furnaces. Those who do not have this knowledge can ascertain from any reliable manufacturer what grade and texture of brick is best suitable for any given service.

When purchasing brick from a new source it is essential that the service conditions be specified, which should include the fuel used. A mere designation of first or second quality clay brick is but meager information.

The brick industry has provided the trade with a great number of brick sizes and shapes known as standards. With these brick most any style of construction is possible, and on account of their lower cost over special shapes and the likely possibility of getting most of them from the makers' sheds or kilns, it is profitable for the user and contractor to bear this fact in mind. Some special shapes, especially skewbacks, are required, but the fewer specials used, the better for all concerned.

One specific recommendation is that where charging-buggies are operated over the furnace floor, or in other furnaces where heavy work is manipulated over the hearth, better results can be obtained by using a hard, dense machine-made block instead of laying 9-inch straights on edge. These blocks can be 4.5 inches thick and any reasonable width or length desired.

Summary

Undoubtedly, marked progress has been made in recent years and is now being made in the manufacture of refractories.

This progress consists in the better knowledge of raw materials, more efficient machinery and equipment for the manufacture of the product, and a clearer appreciation of the needs of the consuming trade. The present work on specifications and service classification will be of great mutual good.

Machine-made brick are just as acceptable as hand-made brick

for the majority of services. The extent of their use depends greatly upon the method of manufacture.

The life of refractories depends primarily upon choosing, or specifying, the correct refractory for any given service, good workmanship in building same into the furnaces and the care or abuse they receive in service. Closer cooperation between consumer and producer will be found exceedingly profitable.

Present clay refractories are entirely satisfactory for steel heat treating work and many other forms of service, but they must be properly chosen and used.

TENSILE PROPERTIES OF SOME STEEL WIRES AT LIQUID AIR TEMPERATURES

By W. P. Sykes

Abstract

In this paper the author has compared the tensile properties of three types of steels, low carbon, nickel and chrome-molybdenum as measured at room temperature and the temperature of liquid air (about —180 degrees Cent. [—292 degrees Fahr.]).

The steels, in wire form, were tested in tension as annealed, as water quenched, and as quenched and tempered at four temperatures between 300 degrees Cent. (572 degrees Fahr.) and 700 degrees Cent. (1292 degrees Fahr.).

Introduction

THIS investigation was undertaken primarily to determine the proper heat treatment for a nickel steel forging, which was to be used at the temperature of liquid air (—180 degrees Cent. [—292 degrees Fahr.]). The requirements called for a material combining a high tensile strength with ductility sufficient to prevent failure, due to the brittleness, which might be expected at this low temperature of operation.

After the specimens of nickel steel had been prepared and tested, it seemed advisable to determine the low temperature properties of steels representing two other classes. For this purpose straight carbon and the chrome-molybdenum steels were selected.

Preparation of Test Specimen

The ¾-inch round bars were turned down to ⅜ inches and swaged hot to about 0.060 inch in diameter and cold drawn to 0.025 inch. The specimens used in these tests were in the form of wires 0.025 inch in diameter and about 3 inches in length between the clamps of the testing machine.

A paper to be presented before the Sixth Annual Convention of the Society to be held in Boston, September 22 to 26, 1924. The author is metallurgical engineer with the Cleveland Wire Division of the National Lamp Works of the General Electric Co., Cleveland. Written discussion is invited.

This type of test piece is easily held submerged in the liquid air bath and cools rapidly to the temperature of the liquid. Moreover, the material after working by swaging and drawing from $\frac{3}{8}$ inch (0.375) to 0.025 inch is exceedingly uniform and the heat treatment and testing can be carried on much more rapidly than is the case with pieces of larger diameter.

The steels as received were in the form of $\frac{3}{4}$-inch round bars and of the following analyses:

A—Carbon Steel		B—Nickel Steel		C—Chrome-Molybdenum Steel	
	Per Cent		Per Cent		Per Cent
C	0.29	C	0.25	C	0.32
Mn	0.61	Ni	3.50	Mn	0.60
Si	0.22	Mn	0.30	Cr	1.01
P	0.02	Si	0.20	Mo	0.43
S	0.03	P	0.020	Si	0.19
		S	0.031	S	0.01
				P	0.02

The wires were treated as indicated in the tables in a resistor-wound tube electric furnace and in an atmosphere of argon gas to eliminate as far as possible surface oxidation. The apparatus used in these tests has been fully described in previous papers.[1] It consists essentially of a firmly fixed standard, carrying at its upper end a hand operated gear which through a worm raises the top clamp in which is fixed the upper end of the specimen. The clamp holding the lower end of the test piece is fitted into the base of a tube which forms a part of a framework resting upon the platform of a springless scale.

The load applied to the specimen by raising the upper clamp is registered on the dial of the scale which is graduated in $\frac{1}{4}$-pound divisions.

For measuring elongation, the test piece was scratched lightly by two diamond points mounted 2 inches apart in a brass base. The test pieces seldom broke at these marks and the few which did fail at them were thus discarded.

Measurements of the reduction of area were made under a low power microscope fitted with a micrometer eye-piece. Several readings were taken on each surface of the fracture.

In making the tests at liquid air temperature, the test-piece,

[1] "Effect of Temperature Reformation and Grain Size on the Mechanical Properties of Metals" by Zay Jeffries, TRANSACTIONS of the American Institute of Mining Engineers., 60, 474, 1919.

clamped in position for applying the load, was completely immersed in the liquid contained in a thermos jar. After violent

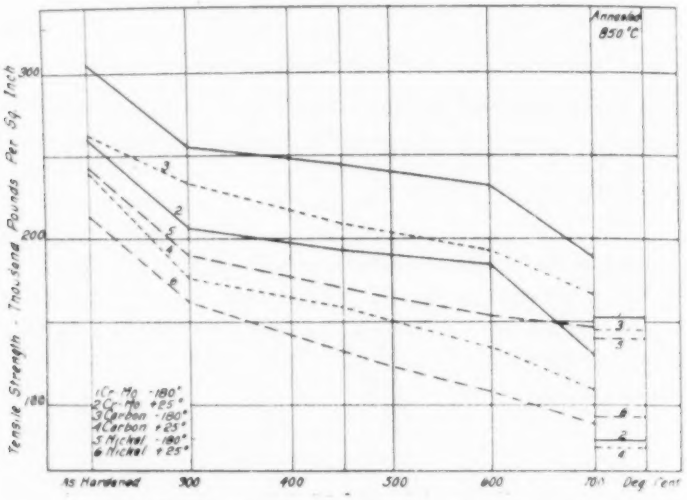


Fig. 1—Tensile Strengths of Steels Water-Quenched from 850 degrees Cent. (1560 degrees Fahr.) and Tempered as Shown.

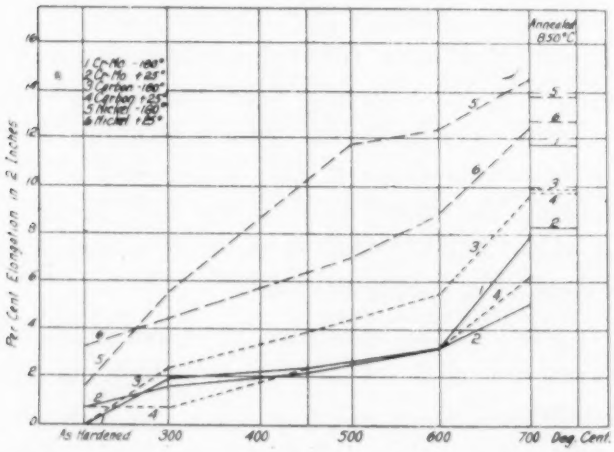


Fig. 2—Elongation of Steels Water-Quenched from 850 degrees Cent. (1560 degrees Fahr.) and Tempered as Shown.

boiling ceased (a period of about one minute), the load was applied to the specimen in the usual manner.

Results of Tests

The values for tensile strength, elongation, and reduction of area of these steels tested at +25 degrees Cent. and −180 degrees Cent. (−292 degrees Fahr.) are recorded in Tables I, II and III.

Table I

Carbon Steel—Diameter 0.025 Inches

Description	Tensile Strength Lbs. per Sq. Inch +25°C.	Tensile Strength Lbs. per Sq. Inch −180°C.	% Elongation in 2 inches +25° C.	% Elongation in 2 inches −180°C.	% Reduction in Area +25°C.	% Reduction in Area −180°C.
Annealed 20 Min. 850° C.	84,000	144,000	9.75	9.87	61	40
20 Min. at 850°— Water Quenched.. and Drawn 15 Min. at	240,000	262,000	0.75	Not Meas.	55	17
300° C.	176,000	234,500	0.75	2.33	68	55
Drawn 15 Min. at 450° C.	158,000	209,500	2.35	3.90	68	52
Drawn 15 Min. at 600° C.	133,700	192,000	3.10	5.50	71	62
Drawn 15 Min. at 700° C.	109,000	167,000	6.25	9.60	73	64

Table II

Nickel Steel—Diameter 0.025 Inches

Description	Tensile Strength Lbs. per Sq. Inch +25°C.	Tensile Strength Lbs. per Sq. Inch −180°C.	% Elongation in 2 inches +25° C.	% Elongation in 2 inches −180°C.	% Reduction in Area +25°C.	% Reduction in Area −180°C.
Annealed 10 Min. at 850° C.	95,000	141,300	8.30	13.80	74	56
Annealed 20 Min. at 850° C.	92,000	139,000	12.75	13.80	75	60
20 Min. at 850° C.— Water Quenched.. and Drawn 15 Min. at	213,000	243,000	3.10	1.55	63	65
300° C.	161,000	190,000	4.40	5.50	..	..
Drawn 15 Min. at 500° C.	121,500	164,500	7.00	11.75	68	62
Drawn 15 Min. at 600° C.	108,000	153,000	8.87	12.30	70	62
Drawn 15 Min. at 700° C.	88,750	146,000	12.50	14.50	77	65

In each case the history of the specimen is noted in the first column opposite the test values.

In Figs. 1 and 2 are plotted the tensile strengths and elongations respectively, of the steels as annealed, hardened and drawn. The highest tensile strength at both temperatures of test is developed by the chrome-molybdenum steel, both as hardened and after tempering up to the temperature of 700 degrees Cent. (1292 degrees Fahr.). It also has a higher tensile strength than the annealed specimens when tested at the lower temperature, but at

room temperature it has a tensile strength of 88,000 pounds per square inch, which is only a little stronger than the annealed carbon steel at the same temperature. The carbon steel takes a place about midway between the chrome-molybdenum steel and the nickel steel, as hardened and tempered.

At both temperatures of the test, the nickel steel shows the lowest tensile strength of the three steels hardened and tempered.

Table III

Chrome-Molybdenum Steel—Diameter 0.025 Inches

Description	Tensile Strength Lbs. per Sq. Inch +25°C.	Tensile Strength Lbs. per Sq. Inch −180°C.	% Elongation in 2 inches +25° C.	% Elongation in 2 inches −180°C.	% Reduction in Area +25°C.	% Reduction in Area −180°C.
Annealed 20 Min. at 850° C.	88,100	150,700	8.23	11.71	65	52
20 Min. at 850°— Water Quenched.. and Drawn 15 Min. at 300° C.	261,000	306,500	0.75	Not Meas.	59	25
	207,700	257,000	1.60	1.95	68	61
Drawn 15 Min. at 450° C.	193,500	245,000	2.07	2.35	66	57
Drawn 15 Min. at 600° C.	183,300	231,000	3.10	3.12	66	60
Drawn 15 Min. at 700° C.	129,500	189,000	5.10	7.90	72	68

In the annealed condition the nickel steel has a tensile strength at room-temperature, which is higher than the annealed specimens of either the carbon steel or the chrome-molybdenum steel tested at the same temperature.

The greatest increase in strength in any of the steels brought about by lowering the temperature of test, is found in the annealed specimens of the chrome-molybdenum steel. In this case, the strength at −180 degrees Cent. is 70 per cent greater than at +25 degrees Cent.

The decrease in strength between specimens tempered at 300 degrees Cent. (572 degrees Fahr.) and those tempered at 700 degrees Cent. (1292 degrees Fahr.) is the least in the nickel steel which loses about 23 per cent as against the 29 per cent decrease in the carbon steel and the 27 per cent decrease shown by the chrome-molybdenum steel.

As hardened, the chrome-molybdenum steel increases in ten-

sile strength most rapidly as the testing temperature is lowered to —180 degrees Cent. The strength at room-temperature is in this case 85 per cent of that at the lower temperature. Of the specimens hardened and tempered at 300 degrees Cent. (572 degrees Fahr.) those of the carbon steel vary the most widely in strength between the two testing temperatures. This steel so treated is 80 per cent stronger at —180 degrees Cent. than at +25 degrees Cent.

After the 700 degrees Cent. tempering treatment, the nickel steel is 36 per cent stronger at the low temperature than at room-temperature, which is the greatest difference encountered in any of the three steels so treated.

Ductility

In all cases the nickel steel has the highest elongation, its maximum being 14.5 per cent as hardened, tempered at 700 degrees Cent. (1292 degrees Fahr.) and tested at —180 degrees Cent. (—292 degrees Fahr.).

In the hardened condition this steel elongates 3 per cent at room-temperature with a reduction of area of 63 per cent. As hardened and tested at —180 degrees Cent. (—292 degrees Fahr.) the elongation is somewhat less, but still nearly twice as great as that shown by either of the other hardened steels at the low temperature. After tempering at 300 degrees Cent. (572 degrees Fahr.) the ductility at —180 degrees Cent. (—292 degrees Fahr.) exceeds that at room-temperature and increases continuously up to its highest value after the 700 degrees Cent. (1292 degrees Fahr.) tempering operation.

The carbon steel attains its greatest elongation, 9.8 per cent, in the annealed state tested at —180 degrees Cent., slightly higher than its elongation at this temperature after the 700 degrees Cent. (1292 degrees Fahr.) tempering operation. However, the 40 per cent area reduction of the annealed specimen indicates a lower ductility than does the 65 per cent reduction in the piece tempered at 700 degrees Cent. (1292 degrees Fahr.).

A combination of lowest elongation and reduction in area is found in the carbon steel, hardened and tested at —180 degrees Cent. (—292 degrees Fahr.). With the same treatment the chrome-molybdenum steel appears to develop a somewhat higher

ductility, as indicated by its 25 per cent area reduction in the low temperature test. The highest reduction in area, 77 per cent, is found in the nickel steel tempered at 700 degrees Cent. (1292 degrees Fahr.) and tested at room-temperature.

In considering the per cent elongation on a two-inch gage length, the small diameter (0.025 inch) of these test pieces should be kept in mind. The elongation value obtained when testing a wire of this diameter will probably represent about one-half of that shown by a test bar having a diameter of 0.5 inch.[2] This relation holds for materials which develop a high reduction in area when broken in tension. As the ductility of the material decreases, and with it the reduction of area, the elongation in pieces of large and small diameter will necessarily approach the same figure.

Summary

Maximum tensile strength is found in the chrome-molybdenum steel either as hardened, hardened and tempered, or annealed, when tested at —180 degrees Cent. (—292 degrees Fahr.).

Maximum ductility, indicated by elongation and reduction of area, is shown by the nickel steel after hardening and tempering at 700 degrees Cent. (1292 degrees Fahr.).

The nickel steel possesses throughout the highest elongation of the three steels tested.

Metallurgical Engineering, Vol. 27, No. 14, p. 696.

[2]Mechanical Properties of Commercial Iron—Zay Jeffries and R. S. Archer—*Chemical and*

A NEW THEORY ON OVERSTRAIN AND STRENGTH OF MATERIALS

By H. P. Troendly and G. V. Pickwell

Abstract

The authors of this paper have cited much old data and have presented new evidence in an outline and connected form, which places the phenomena of overstrain in a fascinating mechanical light. They have evolved a new theory on the mechanics of overstrain and strength of materials, which might be termed—the plastic transfer of the proportional elastic range. They conclude from the evidence which they review and the new data they submit that any strengthening as a result of cold work is not through the formation of a hard amorphous material which renders the section deformed of higher elementary unit-strength, but that the increase in strength in any direction is at the expense of the strength in the opposing direction. Also that the increase in strength in the direction of overstrain is through a mechanism of slip whereby more of the elementary areas or units are allowed to slip into position to assume higher stress in the direction of overstrain.

Introduction

As an introduction to this paper the authors present a resume of present published theories pertaining to elastic and plastic deformation and the mechanism of slip. These include Beilby's amorphous theory and the new theory recently explained and pictured by H. F. Moore and T. M. Jasper[1] in their latest bulletin on the fatigue of metals. The latter theory has been developed more in connection with metals under repeated stress and offers a working theory that explains many of the facts which have heretofore been difficult to explain. The considerations with which

[1] H. F. Moore and T. M. Jasper, "An Investigation of the Fatigue of Metals, series of 1923. Published by the University of Illinois in Bulletin number 142, dated May 26th, 1924.

A paper to be presented before the Sixth Annual Convention of the Society to be held in Boston, September 22 to 26, 1924. The authors are metallurgists with the Wm. D. Gibson Co., Chicago. Written discussion is invited.

the authors deal in this paper are entirely static strength and static overstrain.

Present General Theory

All metals are considered to have an available range of proportional elastic deformation with reference to the various types of distortion, such as, torsion or shear, bending, tension and compression. The magnitude of the elastic range depends upon the composition of the steel and its heat treatment. As plastic deformation occurs, the stress exceeds the elastic limit of the material. If fracture occurs before plastic deformation takes place, it has been considered that the material was too hard to plastically deform, and therefore, fractured without such action. The mechanism of plastic deformation is considered to be a process of slip-band development. The slip-bands form or take place within the crystal cleavage area or along the lines of slip weakness, which probably are crystal strata.

Beilby's Amorphous Theory

Beilby's amorphous theory of cold work and distortion assumes as its working basis that as the material is stressed beyond its elastic limit, regardless of the type of stressing, slip-bands develop and the actual slip area assumes an amorphous nature, which for a very short interval of time is very plastic, but which almost immediately assumes the form of hard amorphous material which has heretofore been assumed to be very brittle and strong and not capable of further distortion. This necessitates additional slip-band areas being developed as further slippage is forced to take place. It is assumed that amorphous metal has a much higher strength than the crystal structure from which it was formed, and as a greater percentage of the total area assumes an amorphous form through the mechanism just outlined, the result is a strengthening of the total section in question. Speaking of amorphous material, Howe[2] states, "this greater strength is natural, because the amorphous state lacks the cleavages and the slip-planes which weaken crystalline substances. Hence the strengthening and hard-

[2]H. M. Howe, "The Metallography of Steel and Cast Iron," 1916.

ening effect of every kind of plastic deformation, which is identical with *overstrain*, *interstrain*, and *cold work*."

Obscurity of Sharp Definition

Practically all writings of investigators who have written on this subject state that all forms of distortion increase the strength of the material, at least over a considerable range. It appears to the authors that most of the writings of the various investigators are obscure in the treatment of their conception of the actual strengthening supposed to result in the amorphous phase. They refer to it as being stronger, but fail to point out whether they imply greater strength such as to resist actual fracture, greater strength or inability to accommodate further slip, or if they conceive of this phase as being able to resist fatigue action under a nominal stress, better than the crystal material from which it was formed. Howe is quite definite and his reader must interpret his conception of the amorphous phase within a slip-plane area, as being hard and brittle and not capable of further distortion without fracture, and as possessing a high elementary unit-strength from a static strength standpoint.

Does Hardening Accompany Overstrain and Cold Work?

Considered from the standpoint of the importance of engineering use of steels, the reverse is usually true, for the writers have discovered that when steel other than dead soft, or annealed, is plastically deformed, the deformed area is actually softened. It is only in the case of an annealed state, slightly cold rolled from an annealed state, or tempered steel drawn back to near the annealed hardness, that any hardening effect following overstrain or cold work is found. The significance of this statement lies in the fact that most writers have stated that amorphous material is the product of slip, and is hard, and renders the deformed area hard in all forms of distortion. The major portion of strength and stress considerations, where limited by low factors of safety, and where precision must attain in dealing with these factors, relate to those wherein steel is used in the ductile, tempered condition. Examples of these conditions may be represented by springs and

flexible parts compared to the condition of harder temper such as machine parts and the like. In this entire range of hardness it is found that distortion softens the distorted areas.

Present Conception of the Strengthening Effect of Overstrain

The apparent present conception that all forms of distortion increase the actual strength and hardness of the deformed area, is the phase of the theory which apparently has been accepted heretofore, and is the statement the authors are prepared to challenge, using experimental evidence as proof. These observations point out the manner in which this evidence breaks down the present belief.

The Authors' Position

The authors desire that this report appear in the light of offering a possible explanation of the facts as they have been observed, and in conjunction with a great mass of data reported heretofore by other investigators. The conclusions which are being presented could be based almost entirely on the work of past investigators and it is only certain phases of the general theory which the authors have found necessary to support with new experimental data developed in this present research. Bauschinger,[3] late in the 19th century, reports a comprehensive investigation, the essence of which supports in detail and without contradiction, the theory the writers are now presenting. Since that time, such men as Unwin,[4] Ewing, Howe, Humphrey, French and many others, have reported similar observations to those of Bauschinger. The authors, for various reasons have repeated many of these observations and have added special experimental data to that previously published, which serve to shed light on obscure points. This revised theory is presented as a more or less rapidly formu-

[3]J. Bauschinger, (a) "Die Veränderung der Elasticitätsgrenze und des Elasticitätsmoduls verschiedener Metalle"; Mitthlg. des mechanisch-technischen Laboratoriums der kgl. Techn. Hochschule. München, Heft 13; also, Dingler's Journal, Bd. 224, and Civilingenieur for 1881.

(b) "Ueber die Veränderung der Elasticitätsgrenze und Festigkeit des Eisens," etc. Mitthlg. aus dem mechanisch-technischen Laboratorium in München, 1886. (See Unwin's "Testing of Materials," also, for Bauschinger's earlier paper.)

[4]W. C. Unwin, "Testing of Materials of Construction," 1910 Ed.

lated working theory which has been developed in a short length of time and which must be reacted upon and rebuilt by men of the science, before it will assume its final form.

Elastic and Plastic Deformation in Torsion

The present theory relating to a straight cylindrical specimen deformed in torsion, considers that the unit stress in the elementary area builds up progressively from the center outward. It considers that the surface fibres reach their elastic limit first, and at this point, all the inner fibres are stressed a lesser amount, depending upon their location with respect to the center of the section. Further deformation beyond this point has heretofore been considered as producing a very complex situation, which has made unit-stress analysis beyond this point, a complicated matter.

The Proportional Elastic Range and Necessity for Further Research

The authors of this paper are particularly interested in torsional stresses, owing to their connection with the spring industry, which involves the use of cold-worked wire embodying the above discussed phenomena. They started investigating torsional stressing with the idea in mind of arriving at an approximation of the outside surface stress condition on a cold-worked specimen. The stress in the torsional specimen is pure shear up to the elastic limit. Beyond this point a double change was conceived to occur. The authors deduced from the amorphous theory, that the deformation beyond this point actually increased the unit strength of the material in question. They further reasoned much along the same line as has been written by other investigators, that slippage occurred more or less in the form of concentric circles, and that as the outside elementary layer reached its elastic limit and was plastically deformed, that the immediately adjacent deeper elementary layer was thereby allowed to be stressed to its unit elastic limit stress, and so on. By this line of reasoning, it could reasonably be assumed that if the cold work or actual twist could be carried far enough, a considerable band of the surface fibres would be at their elastic limit, plus whatever increase of strength the cold work produced. It would appear that if the outside band of a

specimen is actually made stronger, by the mechanism of this plastic deformation, it should stand, without taking set, elastic deformation in a reversed direction from its ultimate cold-worked position, with an angular twist greater than twice that represented by the angular twist of the original positive elastic limit. In other words, the stress represented by the angular deflection, between the proportional elastic limit in the counter-clockwise direction and the proportional elastic limit in the clockwise direction of distortion, may be called the *proportional elastic range*.

Proportional Elastic Range

Steel in the range of hardness in which we find its greatest use, from the standpoint of elasticity and stress, has an available range of proportional elasticity, the actual magnitude of which depends upon the precision of determination. For convenience in determining accurately the proportional elastic limit and also in view of locating this point as near as possible to the point of proportionality of stress to strain, the authors have adopted the point on the curve where the rate of deformation is 10 per cent greater than the rate of elastic deformation. This point is referred to as the *proportional elastic limit*—and the distance, in terms of either stress or deflection, between the two proportional elastic limits in the opposing directions, as the *proportional elastic range*.

If by cold work or plastic deformation the actual strength of these elementary surface fibres is increased, it would be only natural to expect that the proportional elastic range would also be increased. It was upon this scheme of relationships that the investigation was originally planned.

Autographic Torsion Tester Used in the Investigation

An automatic autographic torsion testing machine was designed and built for use in this investigation. The principle of this device, as can be seen from photographs, Fig. 1, 2 and 3, is that the specimen (A) is twisted in tandem with a stronger calibrated specimen (B). A recording drum (C) is located between the

two specimens, so that as the load is applied to the specimen, it also distorts the calibrated specimen, and in so doing, the drum is rotated past the recording pen (D) in proportion to the load. Suitable gaging means (E) and (F) are attached to the specimen

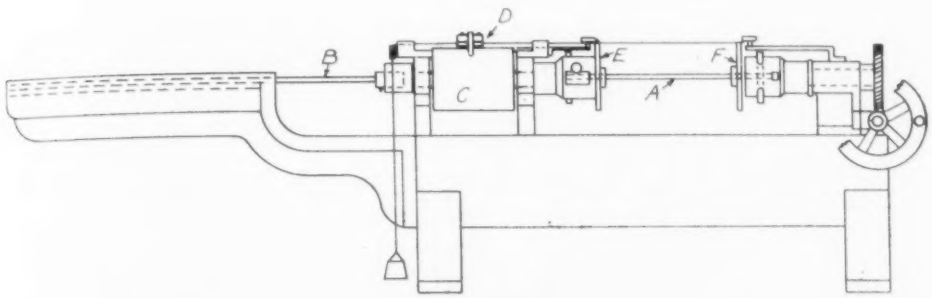


Fig. 1—Diagrammatic Sketch of Automatic Autographic Torsion Tester.

being twisted. This moves the recording pen longitudinally along the drum in proportion to the actual twist over the gage-length of the specimen. It has been possible, by this new type of gaging mechanism, to overcome entirely the effect of all slipping of the

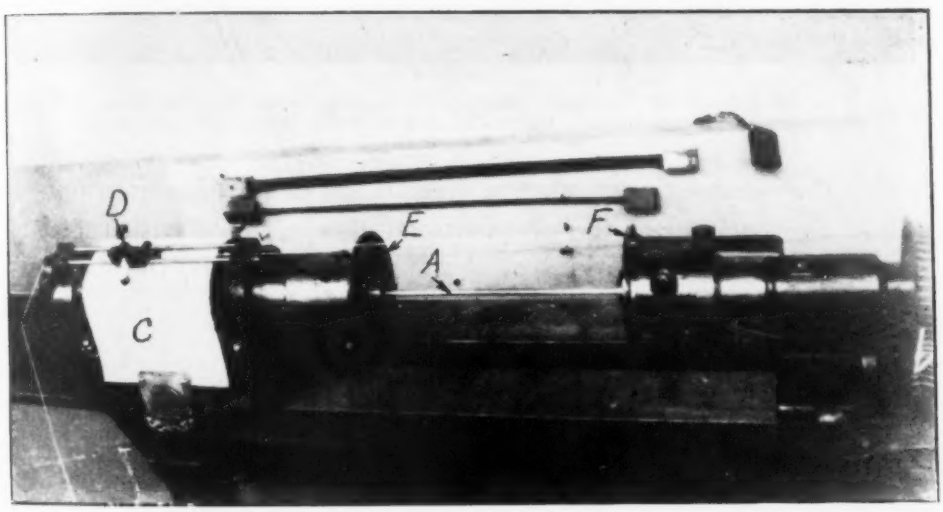


Fig. 2—Photograph of Automatic Autographic Torsion Tester Showing Test Bar A in Position.

specimen in the jaws. This has been accomplished by placing both ends of the cord which advances the pen, on the specimen, through the gaging device, so that as the specimen being tested slips in the jaws, such slip gives to the cord on one end the same

length that it takes from it on the other end. To this instrument has been added a small portable electric furnace (K), for studying torsional specimens under stress, at elevated temperatures. The loading device is so arranged that the specimen can be distorted in either direction, making it a very simple matter to test and to

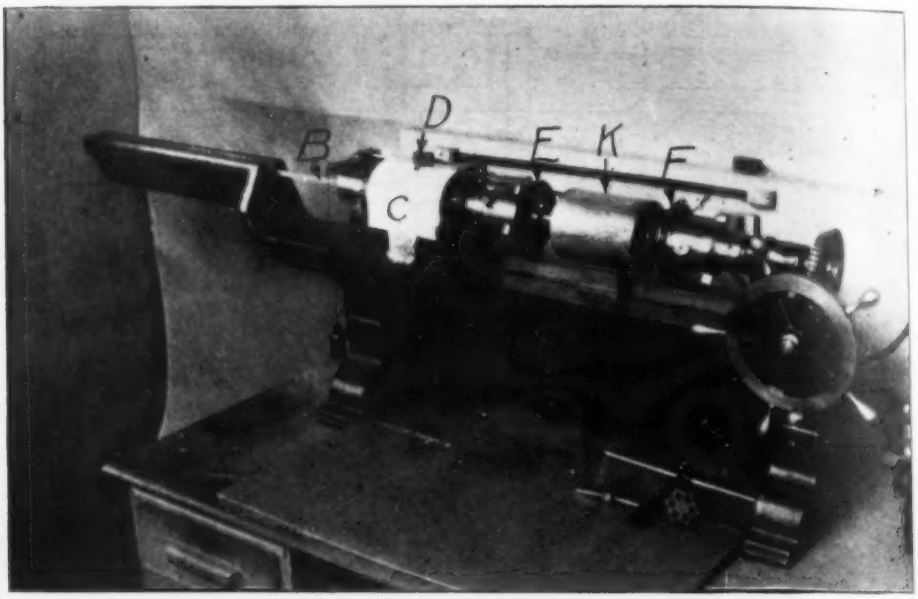


Fig. 3—Photograph of Automatic Autographic Torsion Tester Showing Electric Furnace K in Position.

trace the proportional elastic limit in either direction and to follow the position of the proportional elastic range with reference to the point of equilibrium of the specimen, that is, the condition of zero external load.

Facts which the Investigation have Established

It was noted that the increase of hardness which we have been led to believe necessarily accompanied all forms of plastic deformation was not always experienced. A Rockwell hardness test on a tempered torsional specimen immediately after plastic deformation, regardless of the amount of such deformation, is less than the hardness previous to plastic deformation. If the

specimen is allowed to stand for some time, the hardness shows a slight tendency to return toward its original value. This tendency is increased by a slight rise in temperature. Table I shows the results of hardness tests on specimens overstressed in torsion. The cylindrical specimens were plastically deformed, and readings taken on the surface immediately after overstraining. The readings were secured within ten minutes after overstraining. The specimens were then ground flat, for the purpose of securing more uniform readings. Readings were taken again at various intervals on both the circular surface area and the flat ground area, and the readings recorded as shown. This was done on a set of four specimens representing various degrees of overstrain from a permanent angular set, equal to about four (4) times the angular proportional elastic limit, to excessive overstrain in which the specimen was plastically deformed. This gave an angular set equal to about eleven times the original angular proportional elastic limit. These tests were made as near the fracture point as possible, as it was found that this particular material would fracture if plastically deformed more than twelve times its original proportional elastic limit deflection.

Table I

Data on Torsional Overstress Showing Decrease in Hardness

No.	Ratio of Max. Def. to Elastic Def.	ROCKWELL HARDNESS NUMBERS Original End	Stressed Area	Original End	Surface	Time
1.	4.8	39-40-41	38-37-38	39-39-40	Round	10 Min.
		38-38-39	35-37-36	37-38-39	Round	3 Hrs.
2.	7.5	38-39-38	36-37-37	38-39-38	Round	10 Min.
		38-38-38	36-35-37	38-38-38	Round	3 Hrs.
3.	8.8	42-42-43	38-39-38	41-42-42	Flat	20 Min.
		42-43-43	41-39-42	43-41-42	Flat	24 Hrs.
4.	11.3	38-39-39-38	36-35-35 35 35-34	37-37-38	Round	10 Min.
		40-42-41	37-35 34	39-40-41	Flat	3 Hrs.

Proportional Elastic Range Not Increased by Overstrain

As will be noted from the curve which is shown in Fig. 4, taken from this machine, and which was made from a tempered specimen of about 0.6 per cent carbon, 1.1 per cent manganese, of 35

Rockwell hardness, the actual elastic range of the surface fibres was not increased by overstrain. A quantitative study of the curve as shown in Fig. 4 yields a very interesting set of figures. The original torsional proportional elastic limit is found to be 80,000 pounds per square inch. It was found, from a similar curve shown in Fig. 5, that an identical specimen to the one plastically deformed according to Fig. 4, could be stressed through a reversal of stress, in the original condition, whose magnitude was 160,000 and 80,000 pounds per square inch in each direction.

Study of Values Taken from Curves Secured on Autographic Tester

Referring to Fig. 4, it will be found that the load on the section is increased from (B) to (C) through the mechanism of

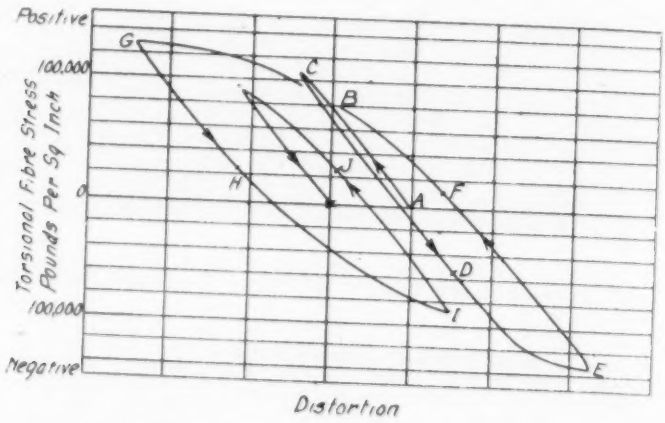


Fig. 4—Curve of Tempered Specimen, 0.6 per cent Carbon, 1.1 per cent Manganese, as Plotted by Torsion Testing Machine.

plastic deformation so that in order to return the specimen to a condition of zero external load, the surface fibres must elastically deform back in the opposite direction 108,000 pounds per square inch instead of 80,000 pounds per square inch, which was their original proportional elastic limit strength. If the difference between 80,000 pounds per square inch and 108,000 pounds per square inch represents an actual increase in the strength of the surface fibres as a result of cold plastic deformation, then the surface fibres should still be capable of being stressed in the opposite direction to the original overstressing, without taking set, an

angular amount equal to 80,000 pounds per square inch. If only a portion of the increase from 80,000 pounds per square inch to 108,000 pounds per square inch, represents actual strengthening of the distorted area, then a lowering of the proportional elastic limit in the opposite direction would be expected. The difference between the sum of the new positive proportional elastic limit of 108,000 pounds and the resulting negative proportional elastic

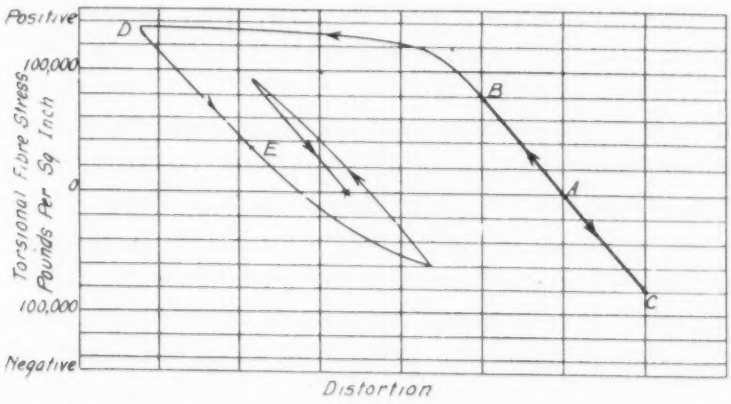


Fig. 5—Curve of Specimen Identical to that of Fig. 4, Stressed Through a Reversal of Stress, in the Original Condition. Magnitude of Stress was 160,000 and 80,000 Pounds per Sq. Inch in Each Direction.

limit, and the sum of the original proportional elastic limits, which is 80,000 times 2, should give the actual strengthening of the surface areas due to cold plastic deformation. It will be noted that as the specimen is distorted in the negative direction, a proportional elastic limit in this direction of 52,000 pounds per square inch, which when added to the new positive proportional elastic of 108,000 pounds per square inch, is exactly equal to the original proportional elastic range as represented by twice 80,000 pounds per square inch. The supposed strengthening effect of cold work failed to appear.

Position of the Proportional Elastic Range Shifted

The elastic range can be transferred clockwise and counterclockwise from the point of equilibrium of the specimen. Referring to Fig. 4, it will be noted that by carrying the distortion beyond the elastic limit in a negative direction, that is, the load is carried beyond the proportional elastic limit of 52,000 pounds per square inch as represented by the point (D), thereby shifting the range to this side of the point of equilibrium of the specimen so that when

cold-worked to (E) in a negative direction, the position of the proportional elastic range is from 134,000 pounds per square inch negative, to a new positive proportional limit of 16,000 pounds per square inch.

It was noted that as the specimen was subjected to severe deformation, the actual proportional elastic range was shortened, indicating instead of the supposed strengthening effect of plastic deformation, an actual weakening. Referring back to Fig. 4 with the negative end of the range shifted to 134,000 pounds per square inch, it is found that the positive end (F) lies at 16,000 pounds per square inch, indicating that as the range shifted negatively, it gave a permanent angular set in a negative direction equal to five-eighths the angular proportional elastic limit. This reduction of the proportional elastic range by 10,000 pounds per square inch amounts to about 6 per cent. Following the curve to (G) and back to (H), it is observed that permanent set in a positive direction equal to twice the proportional elastic limit, lowers the length of the range 34 per cent, etc., each increment of additional plastic deformation tending to shorten the range in proportion.

Proportional Elastic Range Tends to Return to Original Position on Rest and Heating

It was found that the actual location of the proportional elastic range with reference to the zero-load line of the specimen tended to shift back and evenly divide itself with reference to the zero-line when subjected to a rising temperature. It was discovered that the proportional elastic range was not shortened by heat, provided the temperature was not raised beyond the previous drawback temperature of the specimen. Raising the temperature of the specimen, permitted the proportional elastic range to go in the direction of its original location, with reference to the zero-load line of the specimen.

It was found that the length of the proportional elastic range so shortened by excessive overstrain, had a tendency to recover some of its loss when allowed to set for a time, or when subjected to a slight increase in temperature.

Removal of Trapped Stress Area by Acid Etch

A very valuable bit of evidence from the standpoint of the theory which is to follow developed when, by means of acid, the surface was removed from a torsional specimen which had been cold-worked to a considerable depth. It was found, upon removing the surface of such a specimen, that the specimen creeps back, tending to return to its original free position. This occurs in proportion to the depth of surface metal removed.

Mechanics of Elastic and Plastic Deformation as Suggested by This Evidence

The fact that the proportional elastic range has not been lengthened, and that the hardness has not been increased by plastic deformation, except in cases of very soft material, and that plastic deformation enables the section in question to support a greater load than that represented by its proportional elastic limit, suggests that as the outside fibres reach their elastic limit, they are allowed to be bodily transferred plastically in such a manner that the next elementary layers immediately deeper in the section are allowed to be stressed to their elastic limit, and so on. It would appear that such deformation is purely and perfectly plastic, and amounts to a simple bodily movement of those units already stressed to the maximum. This plastic movement would appear to take place under, and to hold, these elementary surface fibres at the same unit stress as they were when the plastic distortion started. It is a fact that the proportional range becomes shorter as plastic deformation is carried to excess, and that the proportional elastic range is always shortened slightly, and in some proportion to additional plastic deformation.

Plastic transfer of the surface elementary areas, once they have assumed their maximum elastic unit-stress, must necessarily allow a deep band on the surface of the material to be progressively, plastically-deformed in such a manner that the entire band is eventually stressed at approximately the same unit-stress.

System of Internally Trapped Stresses Produced by Overstrain

Given a loaded cold-worked torsional specimen, the assumption is

made that the outside band of fibres, to a considerable depth, are under the same unit-stress, namely, the unit-strength of the slip-band area. As the external load on the specimen is released the unit-stress on the entire section decreases. The outside elementary layer of the band, of course, decreases its unit-stress much faster than the deeper layers of this band, so that at the point where the surface elementary areas are at their true-zero unit-stress, the entire inside area of the section is still under considerable stress. The specimen as a whole, in this condition, is supporting an external load which is balanced by these remaining internal stresses. As the external load is entirely removed, the areas of the entire section must find an equilibrium between themselves. From this reasoning a torsional specimen which has been overworked in one direction, and from which all external loads have been released, must necessarily at its surface fibres, be stressed opposite to the direction of overstrain. This stress is balanced by the opposing stress, and is trapped within the fibres deeper in the section, which are still stressed in a positive direction. Somewhere between the surface and the center of the specimen, the fibres are at zero unit-stress, when the cold-worked specimen is free from external load. All fibres of the section are under stress in either a positive or a negative direction in this no-load condition, except at the point indicated.

Lowering Proportional Elastic Limit in Direction Opposite To Overstrain

As the specimen just described is twisted in the opposite direction to which it was cold-worked, the proportional elastic limit in this reversed direction is reached much sooner than would have been the case had the specimen not been previously cold-worked. This naturally follows, inasmuch as the surface fibres in the condition of zero external load were actually stressed materially in a negative direction. It was found, that the actual angular proportional elastic twist possible to give the specimen, from the cold-worked position back to zero-stress and beyond to the point where it starts to take set in the opposite or negative direction, is either equal to twice, or less than twice, the original proportional elastic limit, depending upon the degree of overstrain.

When a specimen is overstressed in one direction and the load is removed from it, it will upon being heated, tend to shift the position of the elastic range toward the original position. This fact goes to prove that internal stresses are trapped within the section.

Readjustment on Removing Surface by Deep Acid Etch Proves Presence of Internally Trapped Stresses

The fact that the specimen when cold-worked in one direction and the load removed therefrom, backs up very appreciably when the surface fibres are removed by a deep acid etch, is a further and a positive proof of the fact that internal stresses are trapped in the section; those on the surface in one direction being balanced by those deeper in the section in the opposite direction.

The direction of movement under an increase in temperature, and under the acid removal of the surface, is in the direction, which from this line of reasoning, outlines the manner in which these internal stresses are trapped. That is, the surface-trapped stresses are in a negative direction, and as they are removed, the angular movement resulting is negative with reference to the angular direction of cold work.

Other Forms of Stressing and the Plastic Transfer Theory

The fact that torsional plastic deformation is not necessarily accompanied by a hardening effect and that no increase in the proportional elastic range is found, calls for a similar investigation of other types of loading. Still other investigations were made into such forms of distortion as cold-rolling. These will be discussed in another part of this paper.

Beam Loading Exhibits Identical Characteristics to Torsion

Beam loaded specimens should exhibit much the same characteristics as torsional loading, inasmuch as the surface fibres on one side of the beam reach their elastic limit before the deeper fibres, and on the other side of the beam the surface fibres reach their

elastic limit in compression ahead of the fibres deeper in the section. The fibres deeper in the section are proportionately at a lower stress, depending upon their depth in the section. It was found that in the bending tests, the position of the proportional elastic range of the bending load can be shifted back and forth with reference to the point of zero external load.

A beam upon being cold-worked by bending is not hardened unless it is of very soft material and for tempered material it is actually softer after being bent, as tested by such instruments as the Brinell and Rockwell hardness testers. In the latter case it was found as in the torsional test on a tempered specimen, that when such a specimen is allowed to stand for a time, it tends to recover its original hardness and that this recovery is increased slightly by raising the temperature of the specimen. It has been found that a beam which has been bent will change its shape if some of the area in which the stresses have been trapped, is removed by filing, grinding or by a deep acid etch. A beam which has been bent, tends to return to its original shape when heated to a temperature below the original drawback temperature given it in the previous heat treatment operations. By slightly heating the specimen, it has been found that the length of the range has not been shortened and further, if the range had been previously shortened by too severe overstraining, this subsequent heating tends to restore the original length of the range. The authors' conception in this case is identical to that in the case of torsion. It must be assumed that the surface elementary fibres of a specimen reach their elastic limit and upon being slipped through pure plastic deformation the fibres deeper in the section are stressed to their elastic limit unit-stress. In the case of the beam, as in the torsional test, the authors conceive of an entire band of the near-surface fibres as being stressed at the same unit-stress when loaded in the cold-worked condition.

Tensile and Compression Type of Elastic and Plastic Deformation

The same scheme of investigation following out the fundamental scheme of plastic transfer of the proportional elastic range

was carried on in the form of straight tensile and compression loading as represented by the ordinary type of tensile bars. Photograph Fig. 6 shows the actual design of the specimen as used, and shows the manner in which the Ames dial was mounted. The dial was graduated to read to 0.0001 inches. With this type of

Fig. 6—Tensile and Compression Test Bar with Ames Dial Attached.

specimen and extensometer application, it was possible to stress the specimen first in tension and then in compression, checking the proportional elastic limits in both directions and following the transfer of the proportional range with reference to the point of equilibrium of the specimen, from the standpoint of external forces.

Previously Reported Evidence

The authors found that even previous to their work on these specimens, that much evidence had been previously reported which

substantiates this present theory. Mr. Bauschinger, H. M. Howe, Mr. Humphrey, H. J. French,[5] and many other investigators report that an increase in the tensile elastic limit due to cold-work results in a corresponding decrease of the compressive elastic limit. H. J. French and others report many other types of phenomena, including those experienced when tension tests are carried on at elevated temperatures and which he finds difficult to

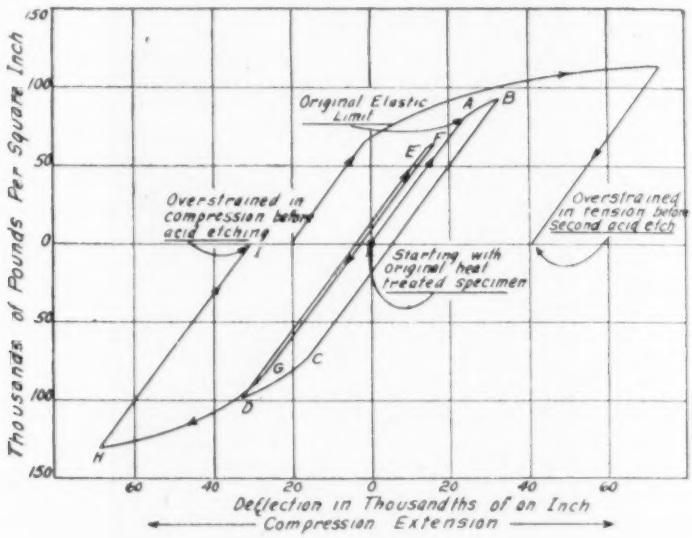


Fig. 7—Compression and Tension Curves Taken on a Tensile-Compression Test Bar.

explain. The authors found that many of these phenomena can be explained by applying to them the theory of internally trapped stresses and the plastic transfer of the proportional elastic range.

Correlating Observations and Additional Tests

The curves of Fig. 7, taken on the tensile bars, offer further evidence along these same lines. The authors found that the tensile proportional elastic limit of the heat treated bar was equal to the compressive proportional elastic within the range of experimental error. They also found, as in Fig. 7, that overstressing the bar in compression by 25,000 pounds per square inch, lowered the limit of tension a corresponding amount, and that as the propor-

[5]H. J. French, Bureau of Standards, "Effect of Temperature, Deformation, and the Rate of Loading on the Tensile Properties of Low-Carbon Steel Below the Thermal Critical Range" Bulletin Number 219, 1922.

tional range was transferred back in the other direction, it held its length, with only a small loss. If the transfer of the elastic range under compressional stress is by means of a mechanism of slippage of concentric layers over each other, starting from the outside and working in so that as the load is released from the section, the stresses would be trapped between the layers, then upon the removal of a surface layer by a deep acid etch, thereby releasing the trapped stress in that section, a change in length of the specimen would occur. This test when carried out, however, failed to disclose such a result. The failure of the authors to find this leads them to believe that the transfer of the proportional elastic range when overstressed in compression, is through the mechanism of slippage and rearrangement of the various elastic units in a rotary manner. In other words, those grains whose cleavage planes or crystalline strata do not line up in the direction of stress may be rotated into this direction as slippage progresses.

Theory of Plastic Transfer of the Elastic Range

This theory assumes steel, considered from a standpoint of elementary units, as being subject to two fundamental types of distortion. A pure elastic distortion is assumed to take place within the elastic bodies which go to make up the material. The other form of distortion, known as plastic deformation, is assumed to take place within the slip plane areas. These areas probably involve a small portion of the total section in question, the greater portion of which is made up of purely elastic bodies.

The function of the slip plane areas are to accommodate plastic deformation, that is, they allow actual bodily movement of the elastic units with reference to each other. The elastic bodies are the portion of the material which undergo all of the deformation up to the elastic limit of the elementary area of the material. They undergo no distortion beyond this point, as plastic flow occurs not within these elastic bodies, but between them and in the slip-band areas.

The strength of each of these, that is, the elastic bodies and the slip-band areas, is probably definite. The unit strength of

the slip-band area must be equal to the actual elastic limit of the material in question. The elastic bodies have an available range of elastic deformation which is probably terminated by an abrupt breaking strength. This point, or better still, the end of the elastic range of the elastic bodies is not reached in steel of ductile qualities because the slip areas allow movement of the elastic bodies before the latter are stressed to their breaking load.

Mechanism of Elastic Distortion and Plastic Slippage

As the specimen is loaded, the elastic bodies assume the distortion until the unit stress reaches the actual strength of the slip-band areas and plastic flow starts, which is commonly known as slip-band development. The growth and further flow through slip-plane areas continue in proportion to additional deformation until the slip-band areas reach the limit of their plasticity and fracture occurs therein. In this case the fracture will probably be transcrystalline or through the slip-plane areas. Steels which are so constituted and so heat-treated that the strength of the slip-band areas exceeds the strength of the elastic bodies, break before taking permanent set. In this case the strength of the slip-band areas has probably not been exceeded and the fracture has probably occurred within the elastic areas which are also transcrystalline. The point where steels fail to be capable of permanent distortion before fracture occurs, is the point where the strength of the plastic areas is equal to or greater than the breaking load of the elastic bodies. Another possible theory might be advanced regarding this point.

There is a possibility that the limit of plasticity is reduced to zero in steels which are so heat-treated that they break before deforming plastically and if this were the case, it might be possible to fracture a specimen in which the unit-stress had not reached the strength of the elementary elastic bodies, but rather had reached the strength of the would-be plastic areas which had been rendered nonplastic by composition and heat-treatment. Slip areas are probably crystalline strata, many of which go to crosshatch a crystal so that the failure of the slip-areas result in transcrystalline fracture. Discrimination between these two working theories will be difficult to effect.

Moore and Jasper Theory of Slip

Quoting from their last bulletin, dated May 26th, 1924,[6] these writers say, "when a light stress is applied to a piece of metal, the effect is to distort the geometrical patterns of atomic arrangement within the crystals—the space lattice, as this arrangement of atoms is often called. This does not change in any way the general scheme of arrangement of atoms. However, as heavier stresses are applied, the bond between adjacent atoms or groups of atoms is broken. Upon the breaking of a bond, one of two things may happen, depending on the nature of the metal and the magnitude of stress: (1) there may result a permanent, though possibly microscopic, fracture between the atoms or the groups of atoms; (2) the bond may be broken between two atoms or groups of atoms and a new bond formed with different atoms or groups of atoms, and this new bond may be as strong or even stronger than the first. Probably in most metals both actions take place under stress.

"The appearance of slip-bands seem characteristic of the breaking of atomic bonds together with the establishment of new bonds. The appearance and spread of cracks and their development toward fatigue failure seem characteristic of the progressive permanent rupture of bonds."

Explanation of Hardness Changes

The combination of this theory regarding two forms of slip and the theories of interference and of obstruction, may offer a possible explanation of the fact that cold-rolling and other forms of distortion as twisting, bending, compression and tension render soft materials harder and render semi-hard and hard metals softer. In the case of the soft, practically annealed metal, the atomic bond can be broken and renewed to the neighbor atom and so on, many times without the formation of any appreciable number of incipient fractures. Soft metal is capable of being plastically deformed to such an extent that it amounts to an actual lining up of the metal into fibres whose direction and whose interference is so uniform and general that they resist such hardness tests as

[6] Loc. cit.

the Brinell and the Rockwell. In considering slightly harder materials, the double type of slippage as pointed out by Moore and Jasper is introduced. As the metal is deformed the bonds are broken and formed. At the same time incipient fractures form so that the one has a tendency to offset the other from the standpoint of the hardness test. As hard metal is deformed, the balance is in favor of the incipient fractures, so that deformation of this

Table II

Hardness Resulting from Various Heat Treatments

Specimen Group Number	1	2	3	4	5	6	7
Drawing temperature in Degrees Fahrenheit	650	725	800	850	925	1050	Annealed
Hardness after drawing	40-41	39-40	38-39	37-38	34-36	30-31	7-9
Number of turns required to fracture*	66	134	184	242	376	357	750
Hardness after fracture	39-40	38-39	35-36	35-36	32-34	29-31	20-23
Hardness after cold rolling to 0.235″ thick	Split on first pass through the rolls.	36-38	34-35	34-35	31-32	29-30	19-20
Hardness after cold rolling to 0.215″ thick		36-38	34-35	34-35	31-32	28-30	19-20
Hardness after cold rolling to 0.182″ thick		36-38	34-35	34-35	31-32	28-30	19-20

*10 turns of the handle of the autographic tester represent the angular twist on the specimen equal to the proportional elastic limit of group number 1 specimens.

material actually produces a softer material due to the formation of the minute fractures. Table II gives the results of a series of tests made on spring steel of 0.6 per cent carbon, 1.10 per cent manganese, in the annealed condition and in the range of hardness representing spring steel temper. It will be noted that in all cases the hardness dropped off on severe twisting and on cold-rolling with the exception of the annealed specimen. The annealed specimen shows a decided increase in hardness.

Table II shows the resulting hardness after various drawing temperatures, number of turns of the handle of the autographic tester required to fracture the specimen, the resulting hardness after fracture and the hardness resulting after rolling the round bar cold to the thickness indicated.

All specimens were of the same composition. All were quenched at 1410 degrees Fahr. and drawn back for ten minutes in a salt

bath to the temperature indicated. The original diameter of the bar was 0.282 inches. All specimens were 57 to 59 Hard in the Rockwell scale of hardness after quenching.

Howe on Amorphous Iron

Howe[7] in his book entitled "The Metallography of Steel and Cast Iron" states on page 190, that one of the undisputed facts on which the amorphous theory is based is that the amorphous iron is much harder than crystalline iron. He then states, "the greater hardness of the amorphous state is familiarly shown by the increase of hardness which wire-drawing and all other forms of overstrain cause in the metals in general, an increase which is now most reasonably referred to the amorphization which the mechanical distortion of the overstrain causes." If the amorphous phase can definitely be proven to be hard, which proof the authors doubt can ever be effected, then, it must follow that amorphous metal is not formed within the slip-plane area. If, however, the amorphous phase is soft and plastic, then amorphous material may be the product of slip. The authors are inclined to think that the amorphous phase is actually a hard phase and can serve as an explanation of the hardening due to rapid cooling of a steel from above the critical range. They are inclined to picture slip much the same as Moore and Jasper, and to imagine slip occurring with no resulting residue in the areas where the bonds renew their grip on adjacent atoms or groups of atoms, and in the case where incipient fracture occurs an actual space area is formed, being filled with the fragments broken from the cleavage face wherein the fracture occurred. This picture would explain the fact that all forms of distortion decrease the density of the deformed area.

Increase in Strength Due to More of the Elastic Units Slipping Into Position to Support Load

The increase in load on the section is the result of bodily movement of the elastic units by means of the mechanism of slip, in such a manner that a greater number of the elastic bodies are

[7] Loc. cit.

supporting a load equal to the plastic strength of the slip areas, which is the elastic limit strength of the material.

Transverse Tensile Tests on Cold Rolled Bars

H. J. French reports that a cold-rolled bar has not had its transverse tensile strength increased as much as the longitudinal. The writers would expect the longitudinal strength to be increased as some function of the actual stretching of the bar. It would be expected that the transverse tensile strength would be increased in proportion to the amount of spread it suffered under the roll, which would not be as much as the stretch it took longitudinally. It would be expected that the compressive strength in a longitudinal direction be decreased according to the stretch of the bar, and that such a treated bar would have a low compressive strength transversally, and a still lower compressive strength longitudinally.

Formation of a Working Theory and Its Development

After the discovery that the torsional unit-stress elastic range of the surface fibres was not increased by cold work, the authors formulated the theory of plastic transfer of the elastic range by the mechanism of slip, and the resulting trapping of internal stress in such a manner, as to allow a greater portion of the area of the section to be stressed to the limit strength of the slip-band areas in the direction of the force in question. They conceived of the behavior of such a scheme in beam loading and in tension and compression. They reasoned that if such were the case, the torsion specimen which had been overstressed would back up on removing the surface with acid, and that the bent beam would straighten out. The authors calculated that a rise in temperature would relieve the trapped stress in the area of high unit trapped stress in the overworked bar and with these expected performances in mind, they planned and carried out the set of experiments described in the paper. Almost without exception, the result of each test verified previous analyses based upon the fundamental idea of the plastic transfer of the elastic range as the

exact explanation of the increase in load which any specimen can be made to support in any particular direction, by plastically deforming it in that direction.

Conclusion

It is to be concluded from the evidence which has herein been presented, that, if amorphous metal is generated or produced by the mechanism of slip, it is not hard and brittle, and above all does not have a higher unit static strength than the crystal from which it was formed. It follows that the increased load on the section experienced is not a result of the supposed production of hard amorphous metal which adds strength to the material as it is formed, but that the ultimate strength of any particular type of stressing is the result of a transfer of the elastic range in the direction of the particular type of stress in question, and that the limit of proportionality of the opposing type of elastic deformation is lowered in direct proportion. The ultimate strength of a material then is somewhat dependent upon the design of the specimen and the plasticity of the slip-plane areas. This plasticity is the determining factor which limits the degree of transfer of elastic range in the direction in question.

This new version of the mechanics of the ultimate strength places the values given for ultimate strengths at elevated temperatures, in a new light. As the material is subjected to elevated temperatures, the rate of plastic lag which is a factor to be considered, becomes of great importance. The magnitude of the plastic lag in carbon steel between 800 to 1,000 degrees Fahr. and above, is a factor of great proportion. A torsion or tensile test of tempered carbon steel at 1100 degrees Fahr., for instance, if conducted very rapidly, will give an ultimate strength of at least twice as high as if the same test were carried out at an exceedingly slow rate of loading. Such a tensile test result is cited by French.[8] The accuracy with which it is possible to determine the elastic limit in the ordinary method also depends altogether on this factor of plastic lag, the slow rate of loading allowing the lag of the deformation to more nearly keep pace with the distorting load. Lack of space prohibits more than a mere mention of this factor.

[8] Loc. cit.

As far as the authors are aware, no one has devised a way to obtain accurate elastic limits at elevated temperatures. This matter affords a field of valuable research. Ultimate strengths are a factor depending on the dimensions of the specimen, rate of loading and the plasticity, as well as the plastic lag. The elastic limit at elevated temperatures is a more fundamental factor and represents the actual elementary unit strength of the slip-plane area at that temperature. It is a factor in which all will eventually be interested, in connection with the use of engineering materials under elevated temperatures.

In a recent paper, V. T. Malcolm[9] says—"It has been noted in nearly all the investigations that at certain temperatures between 500 and 800 degrees Fahr., the tensile strength rises, the elongation and reduction of area decreases, but the elastic limit continues to decline steadily. Therefore, to use the ultimate strength as a basis of design would be far from correct."

The authors believe they are now able, by the use of their autographic torsion tester and a correct understanding of the elastic transfer theory, to obtain the true torsional proportional elastic limit at elevated temperatures, and they will have such figures available on most of the common engineering materials at a later date. So far, they have not been able to plan a test which they feel would yield such figures on the tensile elastic limit.

With the theory of the transfer of the elastic range as a working basis, the authors are able to theoretically draw a fatigue-range diagram somewhat similar to Goodman's diagrams and after so doing, find that they coincide with actual results recently published by H. F. Moore and T. M. Jasper in connection with their work on the fatigue of metals. This theory also explains some odd fatigue results which the authors have also recently secured in their own fatigue investigations. They will endeavor to work up this phase of the theory more completely as time permits.

[9] V. T. Malcolm, "Methods of Testing Metals at Various Temperatures and Their Limitations." A paper presented at the May, 1924, "Symposium on the Effect of Temperature upon the Properties of Metals"—held at a joint meeting of the American Society of Mechanical Engineers and the American Society for Testing Materials, Cleveland.

SALT BATHS

By Sam Tour

Abstract

In this paper are given the results of the author's practical experience in his experimental and development work in connection with the subject of salt baths.

Various reasons for employing liquid heating mediums are considered.

The design of furnaces for the proper melting of salt baths is discussed in detail and a diagrammatic outline to meet the requirements discussed is given.

Containers for salt baths are also considered in detail.

Tables giving the composition of various salt mixtures are incorporated in this discussion.

The author discusses salt baths for the heat treatment of carbon tool steels, alloy tool steels and high speed steels, pointing out the qualities of salt baths which have been observed.

Foreword

THIS PAPER is the third one on this subject contributed by the author to the American Society for Steel Treating.[1], [2] As in previous years, the attempt is made to give a clear and as complete a description of the subject as possible, and to supply accurate data and information.

The author's intention is to give in an unbiased manner the results of his years of practical plant experience and experimental and development work and study of the subject. Having no pecuniary interest in the general adoption or rejection of the salt bath method for heat treating, the author is guided entirely by the proven results of his work, and has no reason for unduly emphasizing either the advantages or the disadvantages of any particular mixture of salts for salt baths.

Much of the data available to the public on the subject of salt baths at the present time, is of the nature of sales propaganda

[1] "Salt Baths for Heat Treating," Transactions of American Society for Steel Treating, November, 1922.

[2] "Salt Baths and Containers for Hardening," Transactions of American Society for Steel Treating, January, 1924.

A paper to be presented before the Sixth Annual Convention of the Society to be held in Boston, September 22 to 26, 1924. The author is metallurgist with the Doehler Die Casting Co., Batavia, N. Y. Written discussion is invited.

and as such is teeming with misleading statements, intentional exaggerations and even with untruths.

General

Liquid baths for heat treating are employed for various reasons. The most common reasons are:

(1) A desire for a non-scaling, non-oxidizing method of heat treating
(2) A desire for a rapid method of producing a skin or surface hardness similar to a thin case hardening
(3) A desire for a more uniform degree of heating of the work
(4) The elimination of troubles due to warping and cracking
(5) An increase in volume of production by more rapid heating
(6) A desire for greater uniformity of product
(7) Lower production costs.

Liquid heating mediums, if properly selected and operated, can usually accomplish a fulfillment of a majority of the above requirements. It is, however, not possible to say, at the present time, that the oven type of furnace for heat treating can be replaced. Consideration should be given to each and every one of the items shown above as reasons for the employing of salt baths before any installation is made.

Surface Requirements of Work

Often, it is of vital importance that work be heat treated without any deterioration of the surface. Again it is often desired to heat a piece so as to obtain a thin skin or surface hardening effect. The surface condition, being the first one to come to view, is the first consideration in the average tool hardening room. Although it is a mistake to consider that "a clean tool is a good tool," yet it is not so often a mistake to consider that "a scaled tool is a ruined tool." The preservation of the surface of the

work is then one of the first requirements of a heating medium. It is usually not only necessary to preserve the surface appearance, but also, except when case hardening, to preserve the surface composition by the prevention of any carburization or decarburization. This requirement is really the one upon which the greatest emphasis should be placed and is often the one which gives the most trouble. The first questions to be raised and answered before one goes any further in regard to the advisability of adopting any specific liquid medium are, "will it scale, pit, corrode, decarburize, cyanide, or carburize the steel to-day, to-morrow, or after continuous operation for a period of several months?" These questions must all be answered satisfactorily before it is advisable to go into the matter further. Each of the above questions will be discussed in more detail below.

Uniformity of Heat

There is no doubt in the matter that liquid bath heating will give more uniform heating of a charge of work than any other type of heating. It is a fallacy, however, to consider that a liquid bath is of the same temperature throughout. The convection currents in a molten bath are the natural result of non-uniformity of temperature in that bath. A molten bath is continually losing heat at the top by radiation into the atmosphere, and when in use, by the carrying away of heat with the work. Normally, then, there will be a tendency towards a higher temperature at the bottom of the bath than at the top, in spite of the fact that convection currents continuously carry the colder liquid to the bottom. There will, of course, be a similar variation between the edge and the center of the bath. In installing and in operating a molten bath, these things must be considered and precautions taken to overcome the difficulties as much as possible. The work placed in the bath must not be allowed to touch the walls of the container. The thermocouple should be properly placed so that it gives an accurate indication of the temperature of the major portion of the bath. When these precautions are taken, the temperature of the bath and temperature of work coming out of the bath can unquestionably be kept more uniform than an oven furnace.

Warping and Cracking

Troubles due to warping and cracking are often traceable to non-uniformity of heating or to an improper rate of heating for hardening. In these cases, the trouble can usually be overcome by the use of properly selected liquid baths and the proper operation of them. The accomplishment of this, however, calls for an understanding of the thermal reactions taking place in the bath and in the work, and the exercising of a certain amount of judgment on the part of the operator. The claim is often made that cracking and warping are due to the shock of too rapid heating during the first few seconds in a furnace, and that cracking and warping of this nature is entirely eliminated in salt baths by the solid film that forms on the work when it is first immersed in the bath. It is further stated that while this solid film is melting, the work heats relatively slowly and as the film gets thinner, the rate of heat increases and when the film is entirely molten, the work heats faster. A little analysis of this statement seems worth while. In treating plain carbon steel tools, a chloride or chloride-carbonate mixture is usually used. Consider a mixture with a melting point of 1300 degrees Fahr. and operating at a temperature of 1425 degrees Fahr. A tool at room-temperature is plunged into this bath. The amount of molten salt necessary to form the solid film must first be cooled from 1425 to 1300 degrees Fahr. The tool must then extract from this quantity of salt, its latent heat of fusion, and it must then in addition cool this solid film down still lower before the solid film can in any way begin to act as a protection of the tool against too rapid heating. The rate of heating during this process is certainly more rapid than could be obtained by placing the tool in an oven furnace at 1425 degrees Fahr. Even after the above process of film formation is complete, the rate of heat transfer into the piece is greater than could be attained in an oven furnace, and anyone can prove this to their own entire satisfaction by running actual tests with thermocouples inserted in test tools. Good practice does not permit the placing of a cold piece directly into a furnace at a cherry red heat. The fact that warping and cracking during initial heating is less common in liquid baths than in oven furnaces, is probably due to the more uniform heating and support of the work in the liquid bath

and not necessarily the result of any lesser rate of heating. If the oven furnace were of the vertical muffle type with open top, and if the work were suspended in this muffle from the top in a manner similar to the method used in a liquid bath, practically the same results would be obtained regarding warping and cracking, providing the muffle furnace were operated at the same temperature as the liquid bath. By proper insertion of the work in molten baths or by proper preheating of the work before such insertion, a great deal of the warping and cracking due to nonuniformity of heating can be eliminated.

Volume and Uniformity of Production

There is no doubt but that a molten bath will heat work faster than an oven or muffle furnace and therefore the work output per furnace can be greatly increased by the installation of the liquid heating medium method of treating. The proper installation and intelligent operation of molten baths allows for a much more accurate and more positive control of temperatures than do oven or muffle furnaces, and therefore the uniformity of the product from day to day can be increased by the use of such baths. The temperature lag between the furnace and the pyrometer is very small and any given temperature can be very accurately maintained with minimum attention. The much more rapid heat transfer from molten medium to the work, than from oven or muffle furnace atmosphere to the work results in increased production per unit of installation and per employee, and in decreased production costs. Often the liquid bath method of heat treating proves the most economical for miscellaneous work not requiring great care as to surface conditions such as in the heat treatemnt. in the rough, of miscellaneous parts of alloy and structural steels.

Furnace Design

To obtain maximum production at lowest cost, any furnace must be properly designed. Mention was made previously of the heat distribution in a molten bath and of the heat losses from a molten bath. Since the zone of maximum heat loss is at the top, it necessarily follows that the zone of maximum heat input should

also be at the top. Containers are often caused to bulge and to crack by the internal pressure resulting from the expansion of the solid salt. By having the furnace hottest at the top the salt melts there first and relieves the pressure below. Efficient furnace operation is always obtained by placing vents so as to remove the gases from the zone of minimum heat input requirements. This means that a molten bath furnace should be top-fired and bottom-vented. Other requirements regarding furnaces are:

(1) The combustion chamber must be free from salt at all times

(2) Separate vents should be provided for the combustion gases and the bath fumes so that no fumes will at any time find their way into the combustion chamber

(3) The furnace should be provided with a bottom drain so that salt may be drained out in case of failure of container

(4) Means should be provided for accurate control of fuel to air mixtures, so as to effect accurate control of the atmosphere in the combustion chamber

(5) The furnace cover should be such as to prevent molten salts dripping from the work from seeping down around the edge or rim of the pot into the combustion chamber

(6) The furnace should be provided with a hood so as to carry away any fumes, to prevent undue spattering and to prevent undue heat loss by radiation.

Forced draft on the hood of a salt bath is not necessary with a proper bath and is not desirable with any bath except cyanide, as it greatly increases the heat loss from the surface of the bath. A furnace designed to meet the above requirements for gaseous fuel is shown in Fig. 1. Furnaces should be so designed as to have no direct impingement of flame on the container. This calls for tangential burners kept in proper adjustment. In using gaseous fuel, it is some times difficult to determine whether proper air-gas mixture is being obtained in the furnace. A valuable aid

to determining this is in the use of a pilot-light from a pet cock tapped into the burner just outside the furnace.

Containers

Containers should be selected with a view towards maximum heat efficiency of the installation as well as towards heat hours service. The thinner the walls of the container, the higher will be the heat efficiency, the shorter will be the time for melting and bringing up to heat, and the easier it will be to control the bath temperature. The life of a container is dependent upon its resistance to the action of the bath, to the strains set up on heating and cooling, and to the amount of external oxidation and chemical attack. Cooling a bath when the temperature gets too high, by shutting off the fuel and leaving the air on, should never be practiced. Strains in containers during heating and cooling arise from expansion and contraction of the container itself, from expansion of the solid salt within during heating and from the fluid pressure of the molten salt. Cast iron containers develop strains due to permanent growth at a red heat. The requirements for a container are:

(1) That they should be as thin-walled as possible
(2) That they should be as strong as possible at the operating temperature
(3) That they should be as resistant to oxidation as possible
(4) That they be of materials other than cast iron if to be operated at a red heat
(5) That they should be resistant to chemical reaction by the salt mixture.

The available method or methods of construction of containers are dependent upon the sizes of container required. Pressed steel pots are not obtainable in very large sizes nor are they usually obtainable in rectangular shapes. Wherever it is possible to obtain a pressed steel pot for the work, such a pot is generally the most economical. For larger pots, cast iron, cast steel and special heat resisting alloys and welded steel pots are available.

For temperatures up to a red heat, cast iron or semi-steel is satisfactory. For temperatures above 1300 degrees Fahr., cast steel, special alloy or welded steel pots are necessary. In all cast pots, the main problem is to obtain them free from porosity. In properly operated furnaces with careful and proper atmospheric

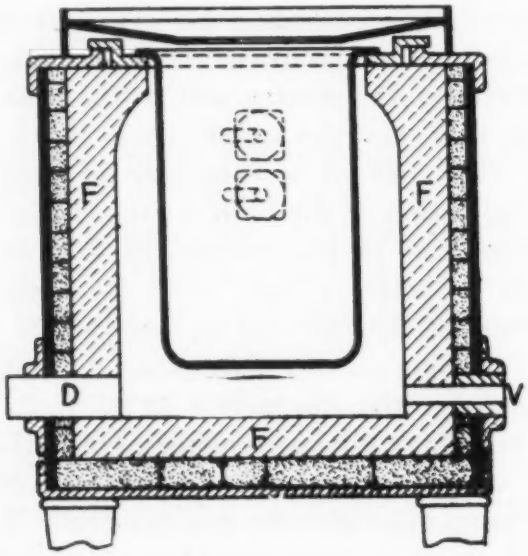


Fig. 1—Diagram of Furnace Using Gaseous Fuel.

control, cast steel and welded steel pots will prove the most economical. If, however, the furnace atmospheres are not properly controlled, then some alloy heat resisting material becomes necessary.

Salt Mixtures for Heat Treating

Various salt mixtures of nitrates, nitrites, carbonates and chlorides are used for heat treating. In Table I is given a number of such mixtures, their composition, melting point and satisfactory working range, together with a few explanatory remarks regarding same. In Table II is given the composition and melting points of the salts used in the mixtures in Table I.

Attention is called to the fact that there is considerable variation among different authorities as to the melting points of a number of the more common salts used in salt bath mixtures. For example, sodium chloride is shown in Table I, as having a

melting point of 1488 degrees Fahr., yet the literature shows considerable variation from this as follows:

Investigator	Reference	Temperature Deg. Fahr.
Wolters	Landolt and Bornstein	1467
Rambach	Landolt and Bornstein	1506
Aureggi	Landolt and Bornstein	1483
.....	Physico Chem. Tables	1422
Day, Sosman and White.	Smithsonian Tables	1472
Le Chatelier	Landolt and Bornstein	1432
Batsford	Industrial and Engineering Chemistry, Vol. 15, p. 1272	1499
Lantsberry	Journal Soc. Chem. Ind. 39, p. 37	1445
Olsen	Chemical Annual	1479

Usually, the best bath composition is that which represents the eutectic mixture of the various constituents of the bath. In Fig. 2, are equilibrium curves for most of the mixtures shown in Table I. In regular practice it is not possible to make up mix-

Table I

Salt Mixtures

Composition	Melting Point Deg. Fahr.	Usable Range	Remarks
55% $NaNO_3$+45% $NaNO_2$	430	430- 900	.....
55% K NO_3+45% $NaNO_2$	425	425- 900	.....
28% NaCl+72% $CaCl_2$	940	1000-1600	Decarburizes above 1500
50% Na_2CO_3+50% K Cl	1040	1100-1500	Breaks down above 1500
50% NaCl+50% K_2CO_3	1040	1100-1500	Breaks down above 1500
35% NaCl+65% Na_2CO_3	1150	1200-1500	Breaks down above 1500
50% $CaCl_2$+50% $BaCl_2$	1112	1200-1650	Decarburizes above 1500
22% NaCl+78% $BaCl_2$	1175	1250-1650	Decarburizes above 1500
54% NaCl—56% K Cl	1228	1300-1600	Decarburizes above 1500

tures of salts shown by these curves and get absolute checks on the freezing temperatures shown. This is due to various impurities in the salts and due to variations in the composition resulting from losses during initial melting. In general, it is not possible to use a salt bath mixture at temperatures close to its melting point, because of the formation of a crust of solid salt on the surface, due to the surface-cooling action referred to under "Furnace Design." The working range then of a salt mixture

will be from a temperature possibly 50 degrees Fahr. above its freezing point up to a temperature at which fuming, scaling, decarburization, or some other objectionable reaction begins to take place.

Table II

Salts

Name	Formula	Melting Point Degrees Fahr.
Sodium Nitrite	$NaNO_2$	543
Sodium Nitrate	$NaNO_3$	590
Potassium Nitrate	KNO_3	642
Potassium Cyanide	KCN	1035
Sodium Cyanide	NaCN	1040
Calcium Chloride	$CaCl_2$	1422
Potassium Chloride	KCl	1454
Sodium Chloride	NaCl	1488
Sodium Carbonate	Na_2CO_3	1560
Potassium Carbonate	K_2CO_3	1670
Barium Chloride	$BaCl_2$	1760

Tempering Baths

For tempering purposes, there is not much choice between sodium nitrate-potassium nitrate and sodium nitrate-sodium nitrite mixtures. They are both usable over about the same range of temperature. They cannot be used for the tempering of high speed steel at 1100 or 1150 degrees Fahr. because at this temperature, they corrode the steel very rapidly. For finely finished work, these salts cannot be used for tempering above 800 or 850 degrees Fahr. because they have an oxidizing action on the steel. For tempering of high speed steels, the calcium chloride-sodium chloride mixture is best, although the potassium chloride-sodium carbonate mixture can also be used. These chloride and chloride-carbonate mixtures do not deteriorate at this temperature and if free from impurities such as sulphates, do not pit or corrode the work or have any cyaniding, carburizing, or decarburizing action.

Cyaniding Salt Baths

Cyaniding is carried out for the purpose of producing a skin or thin surface hardness on steel. The temperature at which the bath is operated is dependent upon the steel being treated and

the amount and depth of case desired. For cyaniding work, straight sodium cyanide or sodium cyanide-sodium chloride-sodium carbonate mixtures are usually used. Sodium cyanide rapidly deteriorates on heating, with the formation of sodium carbonate and the liberation of the cyanogen so that the cyanide content of the bath decreases while the carbonate content increases. If the

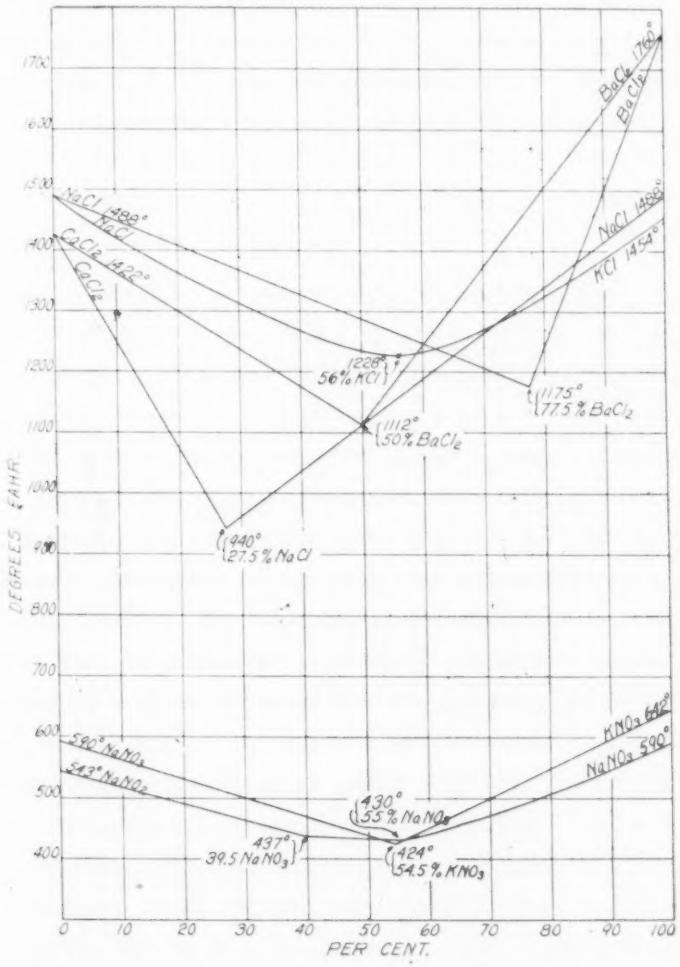


Fig. 2—Equilibrium Curves for Salt Mixtures Shown in Table I.

mixture containing chloride is used at the start, a certain amount of the chloride is lost due to volatilization. Tests have shown that there is no advantage in having a cyanide content over approximately 20 or 25 per cent. Tests have also shown that the cyaniding action takes place with the cyanide content down to a few per cent. To maintain the cyanide content within this range, it

is necessary to add material to the bath from time to time. It is also necessary to add to the bath due to the mixture being lost by being carried out with the work. Tests have shown that as the temperature of cyaniding is raised, the carburizing effect increases and the nitrogenizing effect decreases. On cyaniding at low temperatures, the skin may be raised only a few points in carbon, whereas at temperatures of 1550 and 1600 degrees Fahr., a very high carbon content will be obtained, together with a very material lowering of the nitrogen absorption and therefore a lowering of any possible brittleness due to nitrogen.

Salt Baths for Carbon Tool Steel

Normally, the hardening of carbon tool steels is carried out at temperatures not exceeding 1450 degrees Fahr. For these temperatures, any of the chloride salt mixtures which are shown in Table I and in Fig. 2, are satisfactory if free from impurities which cause pitting, corrosion, etc. Up to 1450 degrees Fahr., there is very little decomposition of the bath and very little tendency toward the development of decarburizing action. Occasionally, a mixture may develop a decarburizing tendency, and in such a case, it is necessary to discard all of the mixture in the pot and start over again. It is not advisable at any time to introduce cold work directly into a molten bath. Moisture has a tendency to accumulate on the surface of cold work and if moist work is introduced into the bath, an explosion may result. Resistance to sudden heating is much greater at temperatures around 400 degrees Fahr. than at room temperatures, and for this reason, in addition to eliminating the danger from explosion due to moisture, work should be preheated to 400 or 500 degrees Fahr., before being introduced into a molten bath. In case a very expensive and complicated and rather bulky tool is to be hardened, it is well to preheat it up to approximately 1000 degrees Fahr., and drop the bath temperature as low as possible before introducing the work into it and then raise both bath and work to the proper temperature. This procedure is also quite desirable where it is desired to minimize growth and shrinkage.

Salt Baths for Alloy Steels

For the hardening of alloy steels which have proper hardening temperatures up to 1450 degrees Fahr, the same baths are available as for the hardening of carbon tool steel. At 1500 degrees Fahr., there is an increased amount of fuming of these baths and at higher temperatures than 1500 degrees Fahr., the decarburizing tendency of the bath increases with its use. In hardening alloy steels, it is usually necessary to soak them at the hardening temperature for a much longer period of time than plain carbon steels, and accordingly, the decarburizing action of the bath becomes more and more noticeable on the finished work. Above 1500 degrees Fahr., the chloride-carbonate mixtures begin to break down and to decarburize the steel and to form a black coating on it which is mostly composed of carbon and iron oxide. It has been stated that the addition of small amounts of carbonates to the regular chloride mixtures results in a decrease of the fuming. Whether or not any such result is obtained is questionable, such practice does result, however, in a tendency towards scaling and decarburizing similar to that which occurs in regular chloride carbonate mixtures. For temperatures above 1500 degrees Fahr., the most adaptable mixtures are the barium chloride-sodium chloride and the barium chloride-calcium chloride mixtures. Due care must be given in all cases to the decarburizing action which will result after long use of the baths.

Salt Baths for High Speed Steel

For the high temperatures involved in the heat treatment of high speed steel, the number of satisfactory salt mixtures are few. The barium-chloride bath was developed and described in detail many years ago but has never been a real success, due to container troubles, to deterioration of the bath, to the developing of pitting and to the excessive fuming at temperatures of 2250 degrees Fahr., or higher.

The use of fluoride salts for these high temperatures has been suggested. The melting points of various fluoride salts and salt mixtures are shown in Table III. These figures were largely

taken from Landolt and Bornstein. Three of these mixtures, namely, the potassium fluoride-sodium fluoride, the potassium chloride-potassium fluoride, and the sodium chloride-sodium fluoride, have been studied. In each case it was found that the molten bath attacked iron very rapidly even at as low a temperature as 1600 degrees Fahr., and that therefore the mixtures were

Table III

Fluorides

Composition	Melting Point Degrees Fahr.
Potassium Fluoride .....KF	1450-1650
Sodium Fluoride .....NaF	1800
Barium Fluoride .....BaF_2	2340
Calcium Fluoride .....CaF_2	2375
Magnesium Fluoride .....MgF_2	2550
63.5% KCl+36.5% KF	1121
72.2% NaCl+27.8% NaF	1247
67.5% KF+32.5% NaF	1292
34% Ba Cl_2+66% BaF_2	1728

not suitable for heat treating purposes. The fourth mixture, namely, barium chloride-barium fluoride, has not been given adequate tests for high speed purposes.

The greatest drawback to the introduction of the salt bath method for the heat treating of high speed steel, is the difficulty with containers and this difficulty overshadows the difficulty of salt mixtures. Ordinary refractory materials cannot be used for containers for salt baths at these high temperatures because of the fluxing action of the salts on the silicates and metallic oxides of which refractories are composed. No metals or heat resisting alloys have been developed as yet which will give satisfactory service. Furnace combustion chamber temperatures required to maintain a bath at 2300 degrees Fahr., are so high that the average container is fused. In some cases, attempts have been made to protect the metallic container with a refractory covering. In this way, it has been possible to use pressed steel pots up to 8 inches in diameter, but their life is only about three days or three heatings, and the temperatures attained are only 2150 to 2200 degrees Fahr. Until a better container is available, there can be

but very little work done toward the satisfactory development of salt baths for the hardening of high speed steel.

Pitting and Desulphurization

Usually, the pitting and corroding of steel in chloride salt baths is a result of impurities in the form of sulphates which are present in the raw materials used in making up the baths. In order to eliminate this pitting action, the bath must be desulphurized. This desulphurization is best and most economically obtained by the addition to the bath of clean cast iron chips. On the addition of these chips, there will result an evolution of gas. This gas rises to the top of the bath and bursts into flame with a peculiar crackling noise. This action is not detrimental to the bath. After heating the bath for a short time, for example, at 1600 degrees Fahr., and in contact with the cast iron chips, these chips should be removed from the bath in order that they may not form a solid layer in the bottom of the container and result in local overheating of the container. There is no particular advantage in the use of ferro-manganese for desulphurizing, nor the use of low sulphur steel chips.

Decarburizing

Mention has been made of the decarburizing action of salt baths in connection with alloy steel hardening. This decarburizing action occurs even in a new bath containing carbonates when operated at temperatures above 1500 degrees Fahr. A decarburizing action develops in chloride baths operated for periods of time at temperatures above 1500 degrees Fahr., and is possibly due to the formation of oxides and carbonates, resulting from the decomposition of the salt bath material at the surface of the bath where it is in contact with the atmosphere. The intensity of the decarburizing action of a bath increases with the temperature at which the bath is operated and with the age of the bath. The depth of decarburization of the work is a function of this temperature and age of the bath together with time period of immersion in the bath. Again, attention is called to the fact that "a clean tool

does not make a good tool," and in spite of surface appearances, decarburization may be present.

Fuming and Changing of Bath

Due to impurities in most of the salts available on the market, the fuming of newly made salt mixtures is greater than of the mixtures that have been in use for a considerable time. New baths for steel hardening can be aged more rapidly, and the fuming action decreased, by heating to 1600 degrees Fahr., once or twice. If a bath develops an objectionable decarburizing action, the easiest way to correct it is to discard the entire lot and use fresh material. It must be remembered that certain salts are hygroscopic, and a bath composed of such salts absorbs moisture. This is especially true of calcium chloride and potassium chloride. Fumes from such baths settling on iron and steel work will collect moisture and will promote rusting. In cases where mixtures containing calcium chloride and potassium chloride are used, great care must be taken to have the furnace properly vented and to carefully wash the work after it is treated, so as to remove the last trace of salt.

ON THE TRANSFORMATIONS IN PURE IRON

By Kotaro Honda

Abstract

Over a period of the past nine years the present writer has discussed, on several occasions, the nature of the A_2 transformation and expressed the view that the A_2 transformation is not a change of phase.

Recent X-Ray analyses have also shown that there is no change of phase below the A_3 point, therefore, the present author considers that this question of long dispute is completely answered. In this paper, the author has also explained the nature of the A_2 transformation, showing that a distinct difference exists between the A_2 change and the ordinary change of phase, like the A_3 and A_4 transformations.

THE word "transformation" is here used in the sense of a change of phase, or in the sense of the change used in the phase rule. In order to distinguish one substance from another, it is usual to compare their properties at a given temperature, usually at room temperature. If these properties are different from each other, it is concluded that they are different substances. But the properties of a substance being changed more or less with the rise of temperature, though two substances have different properties at different temperatures, we cannot conclude that they are different substances. Similarly one substance is said to be "changed" or "transformed" at a given temperature, provided the substance undergoes a discontinuous change of its properties at the temperature, that is, if the substance has two different values of its properties at the same temperature. A familiar example of such a transformation is the melting of ice, that is, the reversible equation;

Ice to Water at 0 degree Cent. (32 degrees Fahr.)

At 0 degree Cent., the ice and the water have different properties,

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A paper to be presented before the Sixth Annual Convention of the Society to be held in Boston, September 22 to 26, 1924. The author, Kotaro Honda, is professor of metallurgy, Tohoku Imperial University, Sendai, Japan. Written discussion of this paper is invited.

by means of which we can recognize the change or the transformation of the substance. During a slow heating, ice gradually changes into water at the constant temperature (Fig. 1). As an example, consider the expansion-temperature curve of water above and below 0 degree Cent., as shown in Fig. 1. The curve dis-

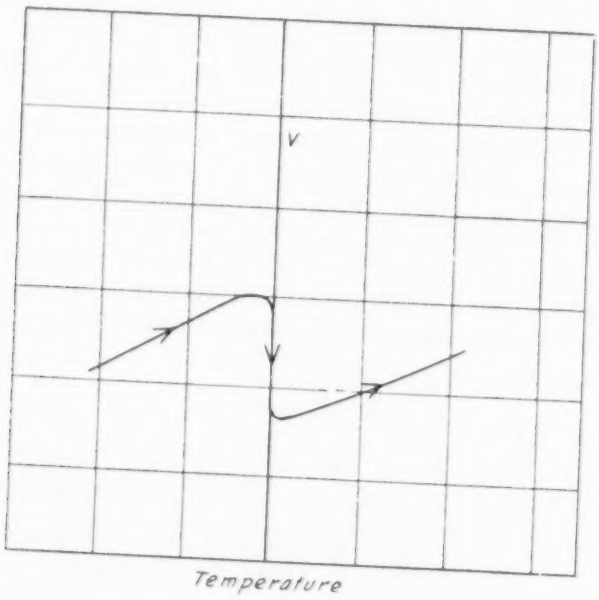


Fig. 1—Expansion-Temperature Curve of Water Above and Below 0 Degree Cent. (32 degrees Fahr.).

continuously falls at 0 degree Cent., the fall taking place at a constant temperature, progresses with time.

On the other hand, consider the case of heating platinum. Its volume increases in an approximate linear relation with the rise of temperature; other properties also change in a similar way, with temperature. Thus, the electric resistance at 1000 degrees Cent. (1832 degrees Fahr.) is about 4 times as great as that at room temperature, but we cannot say in this case that during heating, platinum undergoes a transformation. What, then, is the difference between the change of water and that of platinum? The main point of distinction is, in the case of platinum, that the change in a property is continuous and is a *definite function of the temperature*, and not at all a function of the time. In the case of water, the change of a property at the melting point is *a function of time*. Thus, if we heat platinum at a given temperature for two or three hours, the expansion in length, or the electric

resistance, does not change at all with the lapse of time. In other words, during a slow heating or cooling, the elongation-temperature or resistance-temperature curve has no point at which the elongation or resistance changes discontinuously. From this we see how

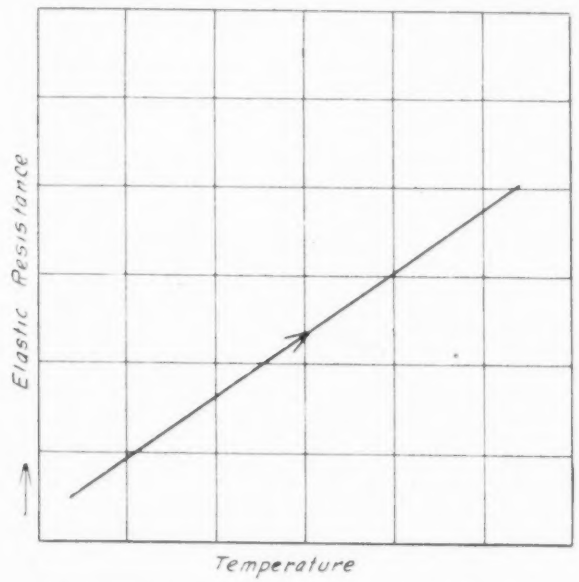


Fig. 2—Resistance-Temperature Curve for Platinum. There is No Point at which the Elongation or Resistance Changes Discontinuously.

the two changes above described differ in their nature from each other. Hence in the case of platinum, though its properties change considerably with temperature, we cannot conclude that it undergoes a transformation, at least in the proper sense of the word (Fig. 2).

Let us consider next the case of heating pure iron. Suppose that we follow the internal change of iron during slow heating, by observing the change of its length. During slow heating,

$$\frac{dl}{l}$$

contracts discontinuously at 915 degrees Cent. (1679 degrees Fahr.), and during cooling, it expands discontinuously at 900 degrees Cent. (1652 degrees Fahr.), as shown in Fig 3. This point is usually called the A_3 point; here every property of iron changes discontinuously; that is, at the A_3 point, each property

has two different values. Hence the A_3 change must be a transformation in the proper sense of the word.

From the view-point of X-ray analyses[1], above the A_3 point, iron has a face-centered cubic lattice, while below it, it has a body-centered cubic lattice. Hence atomistically considered, the

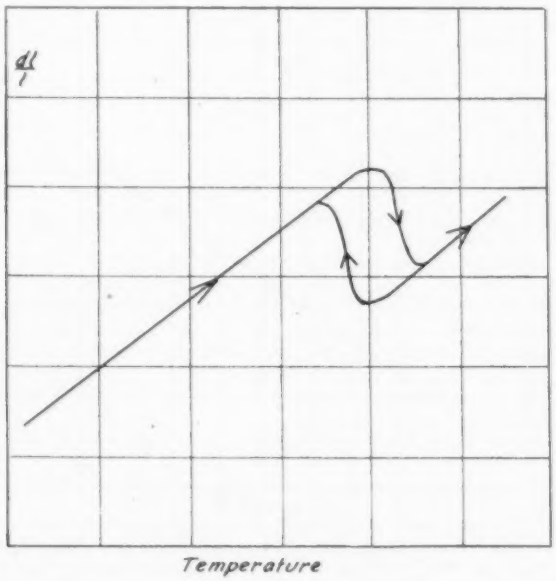


Fig. 3—Heating Curve of Iron Showing Expansion at 915 and 900 Degrees Cent. A3 Discontinuous Point.

A_3 transformation during heating consists of the change of atomic configuration from the body centered to the face centered; thus iron atoms taking the configuration of the closest packing, its volume diminishes during the A_3 transformation, as actually observed (Fig. 3).

Let us consider, next, the change of iron below the A_3 point. We take more conveniently the electric-resistance-temperature curve, as shown in Fig. 4. At the A_3 point,[2] we observe a small discontinuity corresponding to the change of phase. Below the A_3 point, the curve is straight for a short length, but soon begins to bend downward and later becomes nearly straight. The first straight portion, if produced toward the lower temperature, cuts

[1]Edgar C. Bain, *Chemical and Metallurgical Engineering*, Vol. 25, p. 863, 1921. Arne Westgren, *Journal* of the Iron and Steel Institute, Vol 103, p. 303, 1921.

[2]George K. Burgess, Report of the U. S. Bureau of Standards.

the axis of the temperature nearly at absolute zero, as is usually the case with non-magnetic metals. The beginning point of this gradual change during cooling, or the end point of the change during heating, is called the A_2 or critical point, and the gradual bending of the curve corresponds to a progressive change called

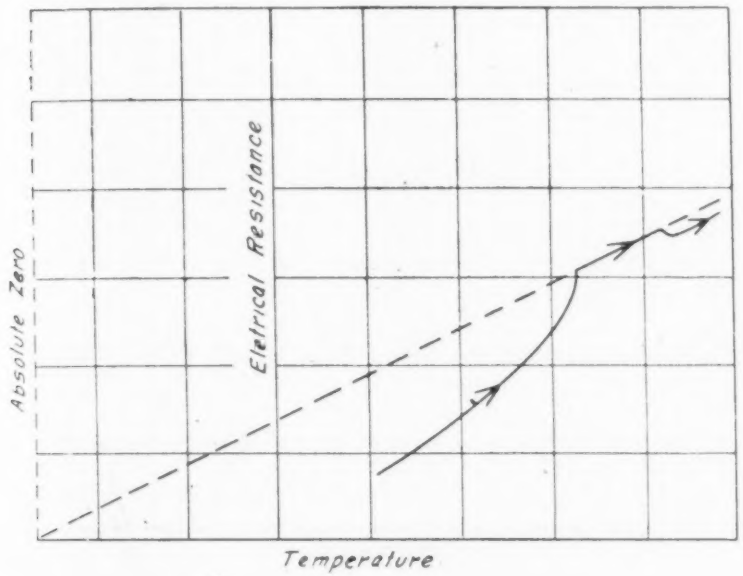


Fig. 4—Curve Showing Change of Iron Below the A3 Point.

the A_3, or magnetic transformation. This change has the characteristics, that the change of the resistance is continuous and has no point of discontinuity with respect to temperature, and that it is a definite function of the temperature, that is, no matter how long we heat the iron at any temperature below the A_3 point, the resistance does not change with time. We observe a similar change for other properties, that is, the change of these properties is perfectly reversible, provided the heating and cooling are conducted in a sufficiently slow rate. Thus, just as in the case of platinum, we cannot consider the change as a transformation. One can object that in the above case, during heating or cooling, we observe a heat effect, but that, in the case of platinum, the same effect is not observable. This latter conclusion is, however, not correct, because, as platinum surely possesses a specific heat, dur-

ing heating, it must absorb heat, and during cooling it must evolve heat.

Thus far, comparing the change of iron below the A_2 point with that of platinum, we can find no essential or qualitative difference between them, and, therefore, we can understand the

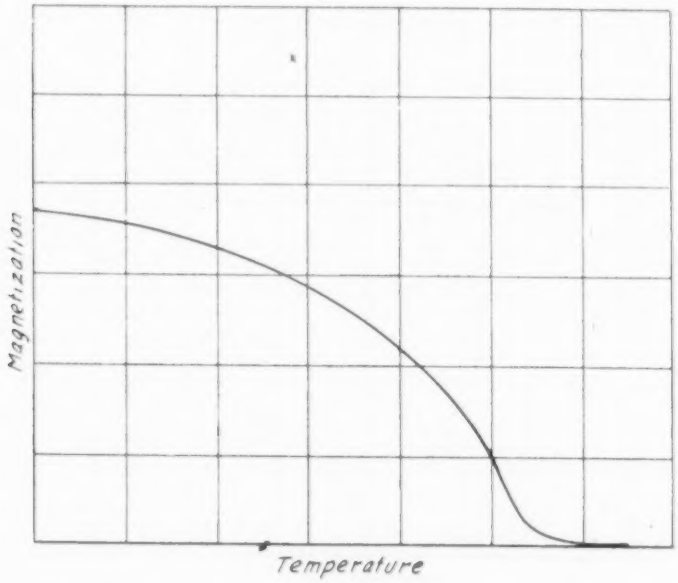


Fig. 5—Curve Showing the Effect of Temperature on the Magnetization of Iron in Strong Fields.

reason why the A_2 change in iron cannot be considered as a change of phase. As a matter of fact, it is confirmed by means of X-ray analyses[3] that below the A_3 point there is no change of atomic configuration, that is, below the A_3 point the atomic configuration remains always in the body centered cubic lattice.

Though the A_2 transformation is not a change of phase, something must go on in iron atoms themselves. According to the theory of magnetism, as proposed by the present writer[4], the change is considered to correspond to the increase of the rotational energy about the magnetic axis of iron atoms. This energy is a definite function of the temperature, as actually observed, and affects the specific heat of the iron by increasing it. Hence, this

[3]Edgar C. Bain, loc. cit., and Arne Westgren, loc. cit.

[4]Kotaro Honda, *Science Reports* of the Tohoku Imperial University, Vol. 141, 1918.

energy is absorbed during heating and evolved during cooling, as a heat effect. Some physicists consider the A_2 change to correspond to some change in the electrons of iron atoms. Even in this case, the change being a definite function of the temperature, cannot be considered as a change of phase. Formerly the iron

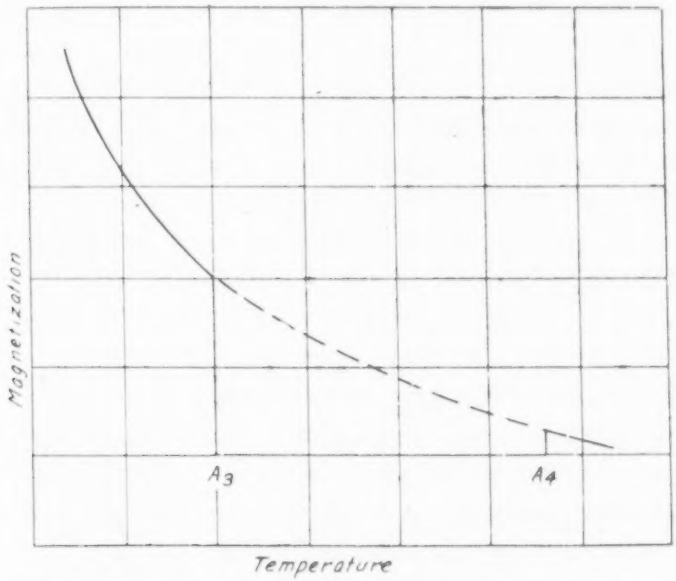


Fig. 6—Curve Showing the Relationship Between Intensity of Magnetization and Temperature Above the A2 Point.

between the A_2 and A_3 points was considered to be a phase different from alpha-iron, and was called beta-iron, but from what we have explained above, it is clear that beta-iron cannot differ in phase from alpha-iron. Hence we conclude that beta-iron is to be excluded.

Our next consideration is the effect of temperature on the magnetization of iron in strong fields, as shown in Fig. 5. The intensity of magnetization diminishes slowly at first as the temperature rises, while its rate of the change steadily increases with the rise of temperature, until the magnetization nearly vanishes at the A_2 point or 780 degrees Cent. (1436 degrees Fahr.). This continuous change of magnetization is another aspect of the A_2 change as seen magnetically. Some metallurgists may consider the magnetic critical point to be different from the thermal critical point, but this idea is not correct. Not only the magnetic and thermal changes are due to the same cause, but also those of any other properties occurring in the same range, are due to the same

internal change going on in iron, and form merely the different aspect of the same change.

Above the A_2 point, the intensity of magnetization is not absolutely zero, and can be measured, if we use a specially sensitive apparatus, such as a torsion balance. The relation between the intensity of magnetization and the temperature above the A_2 point is given in Fig. 6. We see that at the A_3 point, the magnetization discontinuously decreases and afterwards remains nearly constant. At 1410 degrees Cent. (2570 degrees Fahr.) the magnetization increases discontinuously and afterwards gradually decreases. This discontinous increase of magnetization shows also another transformation in iron, for here, other properties also change discontinuously. This change is called the A_4 transformation, and the iron above the A_4 point, delta-iron. By X-ray analysis[5] it is shown that delta-iron has again a body-centered cubic lattice; the A_4 transformation during heating then consists of the change of atomic configuration from the face-centered cubic lattice to the body-centered, that is, from gamma-iron back again to alpha-iron. That this should occur at the A_4 point can be expected from the change of physical properties at high temperature, such as from the magnetization-temperature curve in Fig. 6.

Formerly, four modifications of iron, that is, alpha, beta, gamma, delta were assumed, but at the present time beta-iron is to be excluded as an independent phase and delta-iron is the same phase as alpha-iron. Hence, the four modifications are now reduced to only two, alpha and gamma irons, or atomistically expressed, to the body-centered and the face-centered cubic lattice, there being no other atomic configurations.

It is not out of place to remark that the tensile strength of pure iron discontinuously increases at the A_4 point,[6] that is, in passing from the body-centered cubic lattice to the face-centered cubic lattice. This is easily conceivable, since the distribution of iron atoms in the face-centered cubic lattice is the closest packed, and the atomic force very rapidly increases with decreasing distance. by a given deformation of the lattice, the atomic force developed to resist this deformation will be much greater in the case of the face-centered distribution of the atoms, than in that of the body-centered distribution.

[5]Arne Westgren, *Journal* of the Iron and Steel Institute, No. 1, 1924.

[6]Rosenhain, *Journal* of the Iron and Steel Institute, No. 1, 1916.

ON METALLURGICAL EDUCATION

By Samuel L. Hoyt

Abstract

In this paper the author recommends emphasizing the "fundamentals" in training students to enter the metallurgical profession, allowing the practical side of the education to come largely outside of the curriculum. The idea is illustrated by a brief outline of a course in metallography in which the value of using the constitution diagram and the phase rule as the basis of the study of metallic alloys is discussed. The curriculum, if designed according to the suggestions made, instead of simply training the student in the facts of his profession, would give him an understanding of the guiding principles.

THE IMPRESSION which the writer has gained of metallurgical education in this country, is that it is largely *practical* in nature. The aims and scope of the work for the undergraduate years are designed to give the student familiarity with the tools of the profession, whether these tools be the iron-carbon equilibrium diagram or a commercial heat treating furnace, or the principles of quantitative analysis. While no general statement is rigorously correct, the author believes that it may be safely said that our technical education trains the hands rather than the mind. This statement certainly fits the case far better than the converse. Let us say, then, that we have arrived at the fact of the matter. The next step is:—what of it, is it right or wrong? In such a discussion the writer must speak from the point of view of a research metallurgist, and does so in this paper.

A young man of the author's acquaintance recently asked for his advice as to the proper training for one who has four years to devote to a college education. He wished, of course, to enter the metallurgical profession. The advice which the writer gave him was that he should major in physics and select as the most important secondary subjects, metallography, chemistry (includ-

A paper to be presented before the Sixth Annual Convention of the Society to be held in Boston, September 22 to 26, 1924. The author S. L. Hoyt, is metallurgist at the research laboratories of the General Electric Company, Schenectady, N. Y. Written discussion of this paper is invited.

ing physical-chemistry), and mathematics, and that he work in a practical way during the summer vacation period. The courses in physics, particularly, are to be selected to give him an understanding of the natural laws underlying physical and chemical phenomena, and mechanical behavior, which are of importance in metallurgical practice. His aim will be to determine why the thing works as it does, rather than to learn, first, that it works at all, and second, how it works. In the summer time and after graduation he will find ample opportunity to study the processes and operations with which he may come in contact.

What the author has said to this man, he is pleased to say to this "Symposium on Metallurgical Education," as he believes that this annual meeting of educators may now be regarded as our national clearing house in this field. The theme has been stated, let us now develop it further.

Let us assume that our technical practice, though firmly rooted, is undergoing a constant change and that it will continue to do so for generations to come. In the electrical industry, this is a perfectly rational assumption, and is probably true in other industries. Certainly, to those who attended the joint meeting of the A. S. M. E. and the A. S. T. M., held in Cleveland, May 29, 1924, at which time a symposium pertaining to the study of metals at higher temperatures was presented, learned that such is the case in such a staid field as the generation and utilization of steam. The only safe conclusion is that a new era has now been formally opened up by the High Pressure Congress in Berlin in January, 1924, and the Cleveland Symposium. Similar changes are doubtless occurring in other fields. These points of development in mechanical engineering are offered merely as an example of both the *roots* and the *change*. Such being the case, is it not more profitable for a student to study the fundamental laws in the field of metallurgy rather than the exact manner in which these laws are being applied to present day practice? If this is not self-evident then the fact that a man's most productive time for acquiring his *education* is his four years in college under the guidance of trained leaders, should convince one that such a period should not be used for the acquisition of information which can be better secured after graduation.

Training one's self in college is like climbing up the hill for

a toboggan slide—both produce potential energy and the higher up the hill one goes, the further he can slide when he converts his potential into kinetic energy. This puts our college training in its true light, and in view of the necessity of preparing for a profession which is going to change and develop for years after college graduation, it points out that the college training should prepare the student for what is to come rather than for what now exists. Lest the writer be misunderstood, he hastens to add that the methods of our present practice and their past development are of fundamental importance and that they are the foundation on which the graduate must build. The plea here is that the young man be allowed to acquire this foundation largely outside of his curriculum, or as his first step after graduation. To one in research this seems to be most reasonable and logical. Is it not equally as logical for other branches of the profession?

To be more specific, just what difference is there between a *practical* and a *theoretical* college training? In the field of metallurgy the aims are the same, i. e., to give the student the proper mental equipment and training to follow the metallurgical profession. The difference lies in the modus operandi or the mechanism whereby this is carried out.

One of the leading British metallurgists criticised the methods used at one of our leading metallurgical schools, in teaching students microstructure. In this method, each student is given a box of samples containing about 50 microsections labelled (from memory) A1—cartridge brass; A2—common 60:40 brass; A3—leaded brass, etc., through coinage bronze, bearing bronze, phosphor bronze, babbitt metal, etc. These names may be incorrect, but they illustrate the method. Our British friend held that this method simply gave the student a mass of uncorrelated data, and that such data are of little value, soon to be forgotten. A preferable method would be to give the student a series of correlated specimens from one or more typical alloy systems and to show him how the properties and structure vary with the composition and constitution. With the constitution diagram supplying the key, the subject matter is more easily retained, to become a real tool. He argued that since Nature does not change her fundamental laws from system to system, the thorough study of one system would give the student the key to other systems. The

method employed at this school required the student to learn (and to forget) the microstructure of each technical alloy. The second method would teach the student the true value of the constitution diagram and the fundamental principles of metallography, which, being once learned, could be applied to the study of other alloy systems. Personally, the author agrees with the gentleman.

As an example of this the writer recalls a consultation case which involved the heat treatment of steel. Up to that time the author's training had been in non-ferrous metallography, with which he had combined a study of physical chemistry. The preliminary study of the facts in this case showed that a knowledge of physical chemistry (i. e., the basic principles of metallography), enabled him to handle the problem in heat treatment satisfactorily. The successful use by the client of the recommendations made, offers material evidence of the success of the attempt.

May we not look at this question from another point of view? It will be recalled by many that Dr. Walter Rosenhain visited this country recently, and that on his return to England, he published his impressions of science and technology in this country. One of the main points which the author obtained in reading his account, was that this country is short on the production of fundamental research, but long on the practical adaptation of ideas developed by fundamental research in other countries. If the writer interprets Dr. Rosenhain's statements correctly, it would appear that our college teachers are too busy teaching students things as they are to-day, to devote much time to the study of things as they will be in the future, or to make the contributions which will be involved in the changes. If it is worth while for our industries to make the changes, is it not worth the while of our college faculties to develop the principles which this evolution will follow and utilize?

Now to transfer this line of reasoning to our main theme, it follows that our students should receive their training largely in the *fundamentals*, with less emphasis placed on present technical practice. After all, our present practice is not so difficult or involved that one versed in its principles could not readily grasp it. On the other hand, could one who does not know the fundamentals involved, successfully guide an evolutionary stage of the practice? The author's answer is,—that only by the laborious

and expensive cut-and-try or empirical method could this be accomplished. The logic of this reasoning is, that if students are trained in the fundamentals, they will at once be able to grasp present practice and be in a position to follow or even to guide its future development.

One time during the author's student days when he was at work on copper-rich alloys of tin and zinc, he was discussing with a fellow student the effects of the heat treatment on these alloys. This man had been through the school of steel metallurgy and had learned, empirically, the changes which steel undergoes when heat-treated. Evidently, based on this knowledge he asked whether or not martensite was obtained when copper alloys were quenched. He, of course, was reminded that these were alloys of copper, tin and zinc. But, he said, he supposed that martensite was always obtained on quenching. Since then the writer has noticed that students starting with steel, rather than with the non-ferrous alloys, are apt to think that what they have learned of steel applies generally to other alloy systems. Of course, they soon find out that such is not the case and sooner or later, possibly, that there are certain fundamental laws which underlie all alloy systems. On the other hand it has been noticed that students who have had proper training in physical-chemistry, readily grasp the principles of alloys whether they are brasses, bronzes, or steels. The strain, if there were any, came when they were mastering the Phase Rule and physical-chemistry; the application to metallography came readily and with no great effort. These are the facts as the writer has observed them.

It is believed that it would be far better to teach the student the general principles underlying all metallography and then to take up the application of these principles to special alloy systems and to technical practice. In this scheme one proceeds from the general to the special. If this method is correct for the teaching of metallography, then it is correct for the teaching of metallurgy in general.

Let us now apply this line of reasoning to the design of a "long course" in metallography. It may be assumed that the student has had elementary courses in physics and chemistry, suitable for a junior or senior in a metallurgical school. The whole field of the scientific study of metals is new to him and

yet his future profession requires of him that, sooner or later, he become thoroughly acquainted with the principles and practices of metallography. It is the duty of the college to equip him with the foundations. These are our assumptions.

The first point of attack is the constitution diagram. It is certainly one of the real necessities in the field of metallurgy, although by no means sufficient for all work in metallography. Much of the author's own work is done without reference to any such diagram. But one's understanding of alloys would certainly be deficient if he did not see the correlation of the successive alloys of a system, or the similarities and dissimilarities of different systems, which are pictured by the constitution diagram, or appreciate the information which the constitution diagram gives in heat treatment and forging practice. Starting in this manner is starting with the generalities.

The next thought is that the key to the constitution diagram is the Phase Rule. Consequently, the Phase Rule should appear in the very first chapter so that it can be used for the logical and intelligent study of constitution diagrams. Unless it is used in this way, the Phase Rule may as well be eliminated entirely, for it means nothing unto itself. Those who would put it in the last chapter might better leave it out completely, or else start with the final chapter.

The author has observed, that by starting with the Phase Rule, students readily assimilate such points as the solidification of a binary alloy over a range of temperature, while a pure metal solidifies at constant temperature. A simple application of the Phase Rule shows that the alloy has one degree of freedom, and the pure metal none. At the minimum in the melting point curve (liquidus), the system loses a degree of freedom, in one case because a new phase enters and in another because the concentrations of the phases can no longer vary during solidification, and solidification again must occur at constant temperature. Again, in a binary system the eutectic solidifies at constant temperature, but in a ternary system the binary eutectic solidifies over a range in temperature. Such points as these which might be greatly extended, are fundamental in a study of metallic alloys and they become quite comprehensible when analyzed with the aid of the Phase Rule. The writer knows of no better method of considering them.

It has been argued that the Phase Rule applies rigidly only to systems in equilibrium and that alloys seldom are in that state. Allowing that such may be the case many times, is not such an argument much like the one, that a pathologist would not need to know physiology? Without advancing details, the author submits that the best method of studying the complex behavior of metallic alloys is first to learn the ultimate tendencies of the systems which are required by the laws of homo- and heterogeneous equilibria, and then to study the effects of other factors, such as reaction and diffusion velocities, which are superimposed upon the former. Furthermore, it is often desirable to produce equilibrium in an alloy, even in technical practice, and so for a very direct reason one should study conditions of true equilibrium.

From this point, the student's foundation may be broadened by studying such general subjects as the structure and properties of alloys, correlated to the constitution diagram. In this way he establishes a broad, general foundation for a systematic study of the various alloy systems, and all from the same viewpoint. There is no need of a student carrying the steel viewpoint over into nonferrous metallography, or vice versa; both branches are treated in the same way and with no unnecessary confusion.

Historically we find that the doctrine of the Phase Rule has played a vital part in our industrial life. The spread of the heat treatment of steel may be traced directly to Roozeboom's classical paper, presented before the Iron and Steel Institute of England, on the iron-carbon constitution diagram. Physical chemists, during the latter part of the preceding century, were seeking some general law or rule which they could apply to the study of physical and chemical phenomena. One such attempt was the Le Chatelier Theorem. Unknown or forgotten was the Phase Rule of Prof. Willard Gibbs, which, in its original form, was couched in higher mathematics of such a nature that it was inaccessible to the average scientist. It remained for the Dutch scientist, Bakhuius Roozeboom, to analyze and interpret the Gibbs monograph and to apply the Phase Rule to these phenomena. In England, the eminent scientist and metallurgist, Sir William Chandler Roberts-Austen, was aware of the work of Roozeboom and realized the possibilities of applying such an analysis to the iron-carbon equilibria. At the instance of Roberts-Austen, Roozeboom presented his paper to the Iron and Steel Institute.

Here, then, was the foundation, though not perfect as yet, for the scientific study of steel and its heat treatment and of cast iron. Leading scientists, such as Le Chatelier, Roberts-Austen, Tammann and others, took it up and used it as their guide in the study of steel and other alloys. This paper and the correlated work which came in later years, took the mystery out of the heat treatment of steel, and changed it from a family secret to a subject which could be universally taught in our universities, the same as other subjects. Soon students were learning the present day methods of heat treatment practice, and later as graduates, applying them in industrial practice. It is unnecessary, before this Society, to point out the significance of the heat treatment of steel in our modern civilization. It was Roozeboom, more than any other single person, who "closed the switch" to make this development possible.

While at this point, may not the author make the suggestion that this society do something appropriate to acknowledge the great debt which steel treaters owe to Professor Roozeboom and to perpetuate his name in association with the affairs of the society?

This closes the author's argument in favor of teaching metallography on the broad scientific basis of the Phase Rule and the constitution diagram. The same reasoning should be held to apply to the teaching of metallurgy in general. The fundamentals should be taught and the successful man will apply them, with intelligence and discretion, to the particular problems with which he may have to deal. It is believed that in this way our branch of industry and technology will be materially benefited and the lot of the steel treater made even happier than it is at present.

NOTES FROM THE BUREAU OF STANDARDS

The Effect of Cold Working of Metals upon Hardening

THE progress which the Bureau has made in its study of the effect of cold working on the hardness of metals has been noted in the past numbers of the Bulletin. Work along this line during the past month was largely confined to the preparation of rolled specimens for density determinations. The determinations thus far made show a progressive decrease in density as the metal is rolled thinner and thinner. No reversal corresponding to that found in the hardness curves has been encountered as yet.

Properties of Metals at High Temperatures

The special electric crucible furnace, mentioned in the last Bulletin, was completed during the past month. Four heats were made of nickel-chromium-iron alloys containing additions of cobalt, vanadium, tungsten, or molybdenum. The ingots produced are now being examined chemically and physically, and if sound and of the desired composition, test specimens will be prepared for high temperature mechanical tests.

Two series of tensile tests were made between 20 and 1000 degrees Cent. (1832 degrees Fahr.) on a steel containing 0.3 per cent carbon, 20 per cent chromium, and 1 per cent copper, first water-quenched from 1830 degrees Fahr. or furnace-cooled from 1600 degrees Fahr. Somewhat higher proportional limits, elongations, and reductions of area, but lower tensile strength values, were obtained at all temperatures up to 500 degrees Cent. (932 degrees Fahr.) on the slowly cooled metal. These differences largely disappeared at higher temperatures.

A Meeting of the Gage Steel Committee

A meeting of the Gage Steel Committee was held in Detroit, Mich., on June 17. This is an informal committee organized in January, 1922, for the purpose of studying gage steels and their heat treatment with a view to increasing the permanency of dimensions and resistance to wear of gages used in interchangeable manufacture.

The Committee is composed of steel makers, gage makers, and gage users, all of whom are vitally interested in improving the quality of gages. While a commendable spirit of co-operation has been shown and the progress made is gratifying, much work needs to be done before the many problems involved can be said to have been satisfactorily solved.

A series of steels and a program of heat treatments have been selected which seem most likely to lead to success, and the Committee is now investi-

Information obtained from Technical News Bulletin No. 87, published by the Department of Commerce, Bureau of Standards, Washington.

gating the permanency in wearing qualities resulting from the steels and heat treatments selected. Three types of laboratory wear tests have been conducted at the Bureau of Standards, and while the results obtained are not conclusive, they are reasonably consistent. The laboratory wear tests are now being supplemented by service tests under actual factory conditions.

Effect of Ultra-Violet Rays on Polished Metal Surfaces

This study has been carried somewhat further during the past month with the idea of using a method of this kind as a possible means for corrosion testing. Briefly, the phenomenon as observed is as follows: If the ultra-violet rays are shielded from most of the surface of the polished specimen by means of a thin metal sheet and allowed to play upon a small area, a pronounced change results in the exposed area.

Specimens of armco iron, medium carbon steel, "stainless," and high nickel steels were exposed for 18 hours to the rays. When the specimen is cooled and the moisture of the breath allowed to condense on the surface, the exposed area becomes visible at once. The moisture condenses on this area in a different way from the unexposed parts. The drops of condensation are larger, and the surface looks as though a thin film of oil or similar substance had been spread over it so that it is not wetted so easily as the rest of the surface. In the case of the medium carbon steel, very noticeable corrosion of the exposed spot occurred after four condensations of moisture, while the remainder of the surface was hardly attacked. Chromium and nickel steels did not show any corrosion, although the same difference between exposed and unexposed areas was noticed.

From the above it is evident that the action of the ultra-violet rays plays a part in the surface change of metals.

Examination of Failed Wrought Iron Drawbar

A short time ago the Interstate Commerce Commission submitted to the Bureau of Standards a specimen of a drawbar which had failed in service. The drawbar had been used to couple a locomotive and tender, and it was suggested that as these drawbars are subjected to very severe service which probably results in fatigue of the metal, breakage might be avoided by removing the drawbars from time to time and annealing them, thus relieving the stresses in the metal. However, in this particular case the wrought iron appeared to be of a decidely inferior grade, and this was probably responsible for the failure of the bar under shock. It does not appear that annealing the drawbar would have been of any practical value.

The Compressive Strength of Iron Ore

Bulletin No. 85 mentioned the work which the Bureau of Standards has undertaken for the Bureau of Mines in connection with the strength of iron

ore pillars. During the past month 125 compression tests have been made on specimens of iron ore from the Birmingham district. A portion of these tests were made in the usual manner, while in others the specimens were subjected to vibration during the test by means of a specially constructed device to simulate the conditions in the mines. The strengths obtained varied from 10,000 to 17,000 lb. per sq. in. No appreciable reduction in strength was registered because of the vibrations.

In connection with this investigation, apparatus has been constructed for measuring the elastic properties of the ore and the lateral expansion of specimens due to compression.

New Standard Samples

Renewal of Standard Sample No. 8-C of Bessemer 0.1 per cent Carbon Steel is now being issued with a provisional certificate. The analysis of the new high-carbon ferro-chromium sample, No. 64, was completed and the sample released with provisional certificate the first of the month.

The machining of Renewal No. 9-B of Bessemer 0.2 per cent Carbon Steel was finished in June, and a sample sent to the co-operating analysts the last of that month.

The new sample of Acid Electric Cast Steel, No. 65, is now on the lathes and will probably be ready for analysis about August first.

Physical and Chemical Characteristics of "Plastic Refractories"

An investigation has been started to determine the physical and chemical characteristics of the so-called "plastic refractories" which are used in making rammed-in linings for furnaces. These refractories are used principally around the burner parts and in other places requiring special refractory shapes. Eleven 100 lb. samples have been obtained through the co-operation of the Philadelphia Navy Yard and during the past month the determination of dried strength, drying shrinkage, and the screen analyses have been completed on all of the samples. The data obtained will be used as a basis for specifications.

The modulus of rupture for the dry material has been found to vary approximately from 30 to 110 lbs. per sq. in., while the drying shrinkage, which is an important property for this type of material, does not exceed 2 per cent. In addition, regular 9 in. and 10x3x3 in. shapes have been prepared and are being burned preparatory to testing in the burnt stage.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment — Members Submitting Answers and Discussions Are Requested To Refer to Serial Numbers of Questions

NEW QUESTIONS

QUESTION NO. 133. *In annealing a carbon tool steel of* 1.30 *to* 1.40 *per cent carbon, are there any ill effects to the steel in allowing it to soak for an hour or more at* 30 *to* 40 *degrees Fahr. above the critical point?*

QUESTION NO. 134. *What are the usual feeds and speeds used in machining both carbon and alloy automotive steels, when using high speed steel cutting tools?*

ANSWERS TO OLD QUESTIONS

QUESTION No. 98. *What heat treatment will give a pure martensite structure throughout the hardened area of a piece of steel* 6 *x* 2 *x* 3½ *inches?*

QUESTION NO. 106. *What are the effects of the products of combustion upon both carbon and high-speed steel, when heat treated in open furnaces heated with city gas, coal, coke, fuel oil, etc?*

ANSWER. By Clinton G. Armstrong, manager of furnace department of the Chicago Flexible Shaft Co., Chicago.

In considering the effects of the different fuels on carbon and high speed steels when heat treated in oven-furnaces or furnaces wherein the combustion takes place beneath the hearth and the products of combustion passing over the work above the hearth and out vents above, there are several features to be taken account of.

In the first place, the fuel itself must be clean, that is, not have any impurity such as sulphur or its allied elements present. Sulphur is a very vigorous decarburizer of steel at elevated temperatures and any fuel wherein a considerable amount of sulphur is present, decarburization will take place. The fuels mentioned in this question, city gas, coal, coke, fuel-oil, will be considered separately.

City gas as usually supplied from by-product coke oven or water gas sets carburized with oil to produce 530 b. t. u. gas, is universally desulphurized before being put into the city mains, and normally does not carry any more than just a trace of sulphur. This gas therefore, is a most satisfac-

tory fuel for heat treating. Another feature is that with gas the furnace can be maintained with a reducing atmosphere, that is, an atmosphere within the furnace wherein no oxygen is present, as it is oxygen which together with sulphur (its ally) does the decarburizing. Steel hardened in such a furnace is in the very best condition when hardened.

Gases of other kinds such as blue water-gas and producer-gas are all high in sulphur and nitrogen, and it is difficult to produce a strictly reducing atmosphere using these gases, due to the large amount of air necessary for their combustion. However, it can and is accomplished by careful regulation of the furnaces, and excellent results are obtained, but they do not equal the results with city gas.

The coke and coal fuels, when used in an oven-furnace, produce work which is very unsatisfactory, as normally these fuels are very high in sulphur, and the air supplied to operate them cannot be controlled to the point where a strictly reducing atmosphere is obtainable for any length of time. They are not used except in extreme emergencies.

Fuel-oil when used as a fuel for heat treating in furnaces is accessible to ready control and can, with proper manipulation, produce a reducing atmosphere within the furnace which will be fairly satisfactory, but due to the large amount of air necessary for combustion, and the difficultly in adjustment of this air, prevents oil from being equal to any gas as a fuel for heat treating.

The actual result with all these fuels is that with an oxidizing atmosphere within the furnace, decarburization takes place which may go very deep into the steel and is dependent entirely upon the time and temperature of the steel.

The effect of sulphur in the gases from the fuels is of vital importance and should always be considered, as it is a more vigorous oxidizer than oxygen itself and produces more harm on the work than is generally accredited this "Yellow Devil" of steel industry.

QUESTION NO. 120. *How does the carbon content affect the secondary hardness of high speed steels?*

QUESTION NO. 129. *Does full annealing chromium and tungsten magnet steel, before hardening, affect the magnetic properties? If so, what is the cause?*

ANSWER. By Clinton G. Armstrong, manager of furnace department of the Chicago Flexible Shaft Co., Chicago.

In consideration of the effect of chromium and tungsten or any other alloy of similar character on steel, with respect to its magnetic properties, there are several theories which must be considered, all of which are based on the same fundamental principles. The general theory most accepted today is that when a piece of steel is magnetized, the particles or atoms within the steel are oriented in the self same direction with a positive charge

on one end and a negative on the other, and the characteristic effect of the alloying element is to hold these in this self same fixed position.

Should the steel be worked prior to the hardening, without the annealing taking place first, then the atoms or electrons are not in the self same position before the magnetizing takes place, and it is more difficult to orient them into the self same direction and thus accomplish the maximum magnetic effect. Just what is the cause for this is not readily explained, but the fact remains that full annealing of any piece of steel prior to hardening and magnetizing improves the quality of the magnet to a very marked extent and gives results which are approximately uniform.

QUESTION NO. 130. *Is there any advantage in using notched-bar impact tests in the inspection of annealed tool steel bar stock? What does such a test show?*

QUESTION NO. 131. *Given an alloy of the brass or bronze type, in which there are no critical transformation points, suppose that through carelessness the metal has been overheated, producing an undesirably coarse crystalline structure, is it possible to refine the grain without remelting or mechanical work?*

QUESTION No. 132. Given an alloy of the following analysis as cast, would the addition of vanadium to the extent of 0.10 to 0.20 per cent decidedly improve the following physical qualities in either the "as cast" or heat treated alloy? What heat treatment, if any, should be used to develop the following qualities?

1. Resistance to wear
2. Resistance to dynamic stresses

ANALYSIS

1.80 — 2.20	per cent	carbon	.04	"	sulphur
.50 — .60	"	manganese	.04	"	phosphorus
.30 — .40	"	silicon	1.50 — 2.00	"	chromium

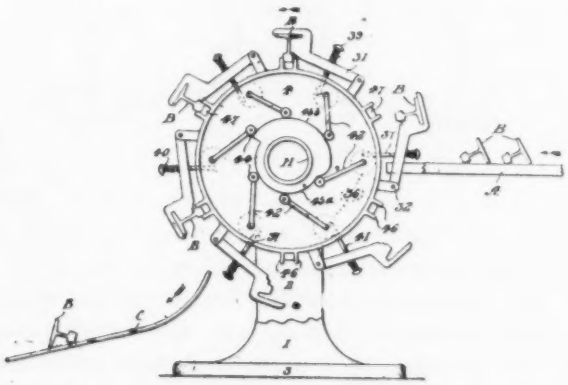
Reviews of Recent Patents

By
NELSON LITTELL, Patent Attorney
110 E. 42nd St., New York City
Member of A. S. S. T.

1,496,531, Method of and Apparatus for Treating Steel, Charles A. Ewing, of Steelton, Pennsylvania.

This patent describes a method and apparatus for treating the heads of steel rails or the like to form a tough sorbitic rail head without producing brittleness in the rail.

The apparatus comprises a revolving hollow drum-like member 4 provided on the outer edges thereof with a series of clamping arms 31 pivoted at 32 and controlled by the arms 42, discs 36 and rods 37 to clamp the rail head against the drum or to permit it to be released therefrom. Inside the



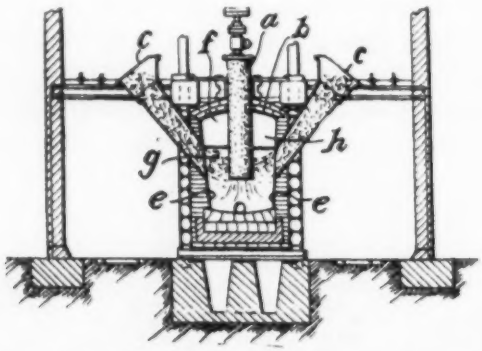
hollow drum a suitable liquid or gaseous quenching medium is maintained under pressure. The heated rails B are fed along the support A and as the drum rotates in a counter-clockwise direction are grasped by the clamping members 31 and as the roller 44 on the arms 42 rides up the raised portion of the cam 11, the rail is clamped with the head thereof between the ribs 46 which run longitudinally of the drum. Valve stems project into the groove 47 between the ribs 46 in a position to be actuated to open the valves from the main drum and permit the quenching fluid to flow into the groove 47 against the heated rail head when the rail is clamped therein. The flow of the quenching fluid continues about one-half way around the drum until the runway C is reached, thereupon the roller 44 of the arms 42 passes down to the lower portion of the cam 11 and permits the quenched rail to drop from the drum onto the receiving platform C. As soon as the rail head is removed from the groove 47, the valves to the hollow portion of the drum close and prevent further flow of the quenching fluid into that groove until another rail head is inserted therein.

The apparatus provides a continuous and automatic means for quenching the heated rail heads without resulting in great loss of the cooling fluid and has other advantageous features.

1,496,674, Closed Electric Furnace, Alois Helfenstein of Vienna, Austria, assignor to Union Carbide Company, of New York, N. Y., a corporation of Virginia.

This patent relates to an electric furnace for the smelting of calcium carbide, pig iron, etc., in which provision is made for advantageous recovery of pure furnace gases.

The furnace comprises a bottom portion e, a raised arch roof b through which the electrodes a are suspended. Charging shafts c extend into the furnace on each side thereof in position to discharge along the side walls



of the furnace below the top portion. This provides a space f between the top of the charge and the roof of the furnace in which the furnace gases may accumulate and into which the charged material never enters. A flue h at the end of the furnace permits the escape of the furnace gases into a settling or collecting chamber. By keeping the charging shafts substantially full at all times or keeping the tops thereof closed, the leakage of air into the gas space is substantially prevented.

1,496,980, Alloy Steel for Metal-Cutting Tools, Percy A. E. Armstrong, of Loudonville, New York.

This patent relates to an alloy steel for metal cutting tools which has general properties intermediate between carbon steel and high speed steel.

It is the object of the patent to provide an alloy which will be cheaper than the high speed steel, but which will not soften under the heat of working or when drawn to medium temperatures such as 500 to 700 degrees Fahr. and can be given a keen cutting edge to produce a smooth finishing similar to that of a carbon steel tool.

The alloy contains chromium, vanadium and molybdenum, etc., and also silicon in excess of the usual silicon contained in steel, the silicon being preferably present to the extent of 0.5 to 2.5 per cent.

It is the theory of the inventor that the large percentage of silicon serves as a sort of solvent for other components and causes them to form

a chemical combination to produce an alloyed steel intermediate between carbon steel and high speed steel having many of the desired properties of each of these classes of steel.

One of the compositions given is:

	Per cent		Per cent
Carbon	1.50	Silicon	2.00
Chromium	2.00	Tungsten	2.00
Molybdenum	2.00	Vanadium	0.50
Manganese	0.40	Cobalt	2.00

The remainder consisting principaily of iron.

1,497,011, Method of Treating Metals, Gustav F. Gerdts, of Bremen, Germany.

This patent describes a method of preparing bearing alloys to meet different conditions of load from one base material to which suitable addition materials are added to form the desired alloy composition.

The inventor proposes to carry in stock a basic soft lead-antimony alloy of low melting point and three other compositions containing various proportions of lead, antimony and tin, of progressively increasing hardness and progressively increasing melting point. The basic composition will produce a bearing for light loads. When the alloy is used for preparing the bearing alloy for progressively increasing loads one of the three addition compositions is added to the molten basic alloy to form a bearing of the desired hardness. The melting point of the addition alloy being higher than the melting point of the basic alloy, the inventor proposes to skim the top of the molten basic alloy and place the addition alloy necessary to produce the bearing of the desired hardness on the surface thereof, and when the addition alloy is melted to stir the charge and pour the casting. Since the melting point of the addition alloy is at the approximate correct pouring temperature an automatic indication of the correct pouring temperature is obtained.

1,498,071, Alloy Steel, W. Norman Bratton, of New York, N. Y., assignor to Climax Molybdenum Company, of New York, N. Y., a corporation of New York.

This invention relates to a manganese steel containing nickel and also molybdenum. The addition of the molybdenum to the nickel manganese steel increases the range of heat treatment and reduces the tendency toward segregation of the nickel manganese steel which permits certain economies in the process of manufacture and at the same time preserves the toughness and strength of the ordinary nickel-manganese steel. One example of the alloy contains 1 to 2.5 per cent manganese, 1 to 1.25 per cent molybdenum and nickel 1 to 3.5 per cent.

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Steel Treaters

HEAT TREATMENT OF CAST IRON. By J. W. Donaldson, in *Iron Age*, June 26, 1924, page 1859.

This article was taken from an address entitled, "Some Experiments in Cast Iron," delivered before the West of Scotland Iron and Steel Institute, published in the *Journal* of the institute for January, and explains the effect of low temperatures on the properties of the metal for parts of Diesel engine, and shows the effect when manganese, chromium and nickel are present.

COMMERCIAL PRODUCTION OF SODIUM HYDROSULPHITE AS A DRY POWDER. By L. A. Pratt, Merrimac Chemical Co., Boston, in *Chemical and Metallurgical Engineering*, Vol. 31, No. 1, July 7, 1924, page 11.

This article was presented before the Division of Dye Chemistry at the sixty-seventh meeting of the American Chemical Society, Washington, D. C., April, 1924, and states that the use of sodium hydrosulphite as a reducing agent in the application of dyestuffs has made this product of unusual importance.

BOOSTING FLAME TEMPERATURES WITH THE ELECTRIC ARC. By George T. Southgate, consulting engineer, Birmingham, Ala., in *Chemical and Metallurgical Engineering*, Vol. 31, No. 1, July 7, 1924, page 11.

The above gives an account of a newly developed method of increasing the heat available from fuel combustion by electricity.

HARDENED AND GROUND FORGED STEEL ROLLS. By J. R. Adams, superintendent, research department, Midvale Co., Nicetown, Philadelphia, in *Forging, Stamping and Heat Treating*, July, 1924, page 255.

A paper read before the American Iron and Steel Institute at New York City, May, 1924, which states that forged steel rolls possess advantages over chilled iron rolls, of greater hardness, more homogeneous surface, greater strength and longer life.

PICKLING OF IRON AND STEEL; A BIBLIOGRAPHY. Compiled by Victor S. Polansky, Carnegie Library of Pittsburgh, in *Forging, Stamping and Heat Treating*, July, 1924, page 267.

The above article is the first of a series of three articles covering the available literature on the pickling of iron and steel, general, miscellaneous, mechanics and equipment.

PROPERTIES OF CAST 12 PER CENT MANGANESE STEEL. By John H. Hall and G. R. Hanks, metallurgical engineer and superintendent,

Taylor-Wharton Iron and Steel Co., High Bridge, N. J., in *Forging, Stamping and Heat Treating*, July, 1924, page 271.

This paper was presented at the twenty-seventh annual meeting of the American Society for Testing Materials, Atlantic City, N. J., and covers the methods employed in making manganese steel, its heat treatment, metallography and physical properties. The average composition is also given.

DENSITY INDICATES SOUNDNESS. By T. G. Bamford, in *Foundry*, May 1, 1924.

The above was presented at the meeting of the British Institute of Metals held in Birmingham, England. The author states that the analysis shows the composition, while density determines the condition of the casting. Results obtained by former investigators are given and a new method for determining density is outlined.

ACTION OF LEAD UPON ALLOYS. By George A. Drysdale, in *Foundry*, May 1, 1924.

This paper discusses the obstacles which have to be overcome in the melting and production of satisfactory castings from alloys suitable for use in mine pumps and accessories.

NOTES ON THE PROPERTIES OF CAST IRON. By Enrique Touceda, in *Foundry*, May 1, 1924.

The author of this article states that the manner and condition under which graphitization takes place in cast iron, has a profound influence upon the chemical and physical properties of the metal. He also describes a special metal.

FUNDAMENTAL ECONOMIES OF MATERIALS HANDLING. By Prof. M. L. Begman, University of Michigan, Ann Arbor, Mich., in *Mechanical Engineering*, July, 1924, page 405.

The author discusses the advantages of handling materials mechanically without reference to particular types of equipment. He states that by the mechanical handling of materials, production is increased, greater speed is obtained, labor expense is reduced, floor space is minimized and overhead expense decreased.

THE CARRYING CAPACITY OF BALL BEARINGS MADE OF STAINLESS STEEL. By Axel Hultgren, chief metallurgist, Aktiebolaget Svenska Kullagerfabriken (SKF), Gothenburg, Sweden.

This paper was presented at the June meeting of the American Society for Testing Materials at Atlantic City and presents a brief summary of a series of tests on stainless steel as a ball-bearing material, which was conducted at the laboratory of the company with which the author is connected. The results of the tests were far from promising, the carrying capacity of the stainless steel bearings tested being from 10 to 20 per cent of that of the ordinary ball bearings. Hence the conclusion is that these steels are much inferior in their carrying capacity to ball bearings made of ordinary material and are only slightly superior to the ball bearings made of bronze.

News of the Chapters

NEW HAVEN CHAPTER

The New Haven chapter of the American Society for Steel Treating held a meeting on Friday, June 20th, at the New Haven Yacht Club. The speaker of the evening was Prof. V. O. Homerberg, Massachusetts Institute of Technology, Cambridge, Mass., who chose for his subject "The Detection of Defects in Steel without the Use of a Microscope." This meeting was very well attended. Dinner was served at 6:30 p. m. preceeding the meeting.

PHILADELPHIA CHAPTER

The Philadelphia chapter of the American Society for Steel Treating held a picnic on Saturday, July 26th at "Best Lyn" Farm, near Langhorne on the Neshaminy Creek. A very enjoyable afternoon and evening were spent by all who attended.

The Library Committee of the Philadelphia chapter of which Theodore Wiedmann is chairman, is doing a very commendable piece of work in an endeavor to establish a technical library. The committee would like to have the co-operation of the chapter members in this work and have sent out the following questionnaire.

"Science, as you know, is moving forward by leaps, new knowledge brings new methods and revises old ones, processes are changed over night; not one individual's experience can cover all branches of a single art. To keep abreast of progress we must review the work of others through their writings.

"But even this is not easy, the literature is voluminous and scattered; therefore, should each of us individually attempt the assemblage of a bibliography for his personal use, the lost motion due to duplication of effort by the numerous members of our Society would be enormous and wasteful.

"Our officers believe "Co-operation is the Solution" of this problem and have appointed the undersigned as a committee to arrange for the acquisition, care and regulation of a library to be owned and controlled by this chapter of the Society.

"After much discussion and careful thought, the following plan is submitted with the confidence our membership will view this work, not as an expense, but as a dividend earning investment inasmuch as it will make available to all, especially our student members, the best and latest reports of our co-workers throughout the world.

The Committee asks:

"1st: That you send in a list of the books and periodicals you would most like to have provided (use card enclosed)

"2nd: That you contribute to the library any books, periodicals (bound or unbound) you can spare from your collection. (The society will arrange full credit be given you by suitable inscription in each volume.) The items may be sent to Theo. Wiedemann, Chairman, 1815 Sedgley Ave., accompanied by a list on attached card.

"3rd: Books are especially desired on the following subjects:

Alloys
Cementation
Metals History
Metallography
Macrography
Photo Micrography
Physical Testing of Metals
Pyrometry

Magazines devoted wholly or in part to the above.

"4th: Cash subscriptions to Library Fund are invited. (But it is not desired to interfere with your plans for the donation of Scholarships to courses in metallography or subscriptions to other efforts.) As nearly as possible each subscription will be used to purchase a definite number of volumes to be inscribed as stated above."

ST. LOUIS CHAPTER

The first of the summer meetings of this chapter was held on Monday, July 21st at the American Annex Hotel at 8:00 p. m. Through the courtesy of the Oxweld Acetylene Company, a series of motion pictures were presented, showing typical applications of the oxy-acetylene welding and cutting process. The film was explained and discussed by T. R. Beebe, who is the St. Louis representative of the company. "The Cleaning and Pickling of Sheet Metal" was discussed by the local members and demonstrations of different compounds were included in the discussion. Dinner was served at 7:00 p. m. preceding the meeting.

ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J represents Junior Member; and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

NEW MEMBERS

ALVERSON, W. A., (M-5), heat treating department, Doble Steam Motors Co.; *mail* 2612 Monticello Ave., Oakland, Calif.

ATKINSON, LEON, (M-7), assistant in laboratory, North East Electric Co., Rochester, N. Y.; *mail* 20 West Park St., Albion, N. Y.

BARNARD, R. J., (M-7), partner, Worcester Steel Stamp Co.; *mail* 44 Portland St., Worcester, Mass.

BELAIEW, N. T., (M-7), 33 Elvaston Place, Queens Gate, S. W. 7, London, England.

BROKAW, D. G., (A-7), salesman, General Electric Co., Boston.

D'ARDENNE, WALTER, (M-6), mechanical engineer, Heintz Manufacturing Co.; *mail* 1004 Robbins Ave., Philadelphia.

DAVIS, H. A., (M-6), superintendent, Fremont Castings Co.; *mail* 105 Fremont St., Worcester, Mass.

DOW, F. E., (M-7), foreman, heat treating, Mathias Klein and Sons, Chicago; *mail* 214 North Vernon St., Brookfield, Ill.

DULLIGAN, C. E., (M-7), overseer, radiator and radiator tube manufacture, U. S. Cartage Co.; *mail* 11 Sydney St., Lowell, Mass.

FREITAG, C. M., (M-7), vice-president and general manager, Thurston Manufacturing Co.; *mail* 140 Benedict St., Providence, R. I.

GARDNER, A. A., (A-4), Pacific Coast manager, Henry Disston and Sons, Inc.; *mail* 322 Occidental Ave., Seattle.

GEESEY, C. U., (M-7), chemist and metallurgist, Superior Foundry Co., Cleveland.

GEIS, F. R., (M-5), Charles Kawin Co., San Francisco.

GUMZ, J. H., (M-5), engineer, Pacific Gas and Electric Co., San Francisco.

HALL, G. C., (S-7), general manager, Atlas Tack Corp., St. Louis.

HEYMANN, B., (M-5), instructor, Lick-Wilmerding School; *mail* 38 Woodland Ave., San Francisco.

HICKOK, G. F., (A-5), Hickok & Hickok, 489 Bryant St., San Francisco.

HOFF, G. M., (M-7), foreman, Columbia Steel Corp.; *mail* 309 East Sixth St., Pittsburg, Calif.

KRUTZSCH, CARL, (M-7), manager, Southern Manganese Steel Co., St. Louis.

LITTLE, EDWARD, (M-6), shop superintendent, Hoover Spring Co.; *mail* 675 Castro St., San Francisco.

LORD ELECTRIC COMPANY, (S-6), 112 Water St., Boston.

MACGREGOR, L. J., (M-7), chief of standards, Bonney Forge and Tool Works, Allentown, Pa.

MACKENNEY, L. A., (A-6), salesman, General Electric Co., Worcester, Mass.

MAPES, P. P., (M-5), inspector, Hall-Scott Motor Car Co.; *mail* 2617 Channing Way, Berkeley, Calif.

MARTIN, D. H., (M-7), manager, Big Four Truck Co., Puente, Calif.

MICHEL, A. J., (M-7), assistant metallographer, Ingersoll Rand Co.; *mail* 8 Summit Ave., Phillipsburg, N. J.

MURPHY, M. J., (M-5), research engineer, C. L. Best Tractor Co., San Leandro, Calif.

NEELEY, M. E., (M-6), partner, Horace T. Potts and Co., Philadelphia.

PALMGREN, C. A., (M-6), Damascus Steel Products Co., Rockford, Ill.

QUINN, G. F. S., (A-6), salesman, New England Oil Refining Co., Brighton, Mass.

ROBERTS, J. T., (M-5), vice-president, Stockton Fire Brick Co., San Francisco.

ROBINSON, T. L., (M-6), Strom Ball Bearing Co., Chicago.

ROGERS, R. G., (M-6), foreman, heat treating, Dayton Engineering Laboratories Co., Dayton, Ohio.

SCHNECK, P., (M-7), mechanic, S. G. Taylor Chain Co.; *mail* 130 142nd St., Hammond, Ind.

SCOTT, G. H., (M-7), secretary, Metal Auto Parts Co., Indianapolis.

SMITH, E. L., (A-7), sales manager, Heat Treating Supply Co., Sandusky, Ohio.

SMITH, W. A., (M-7), engineer of tests, Greenfield Tap and Die Co.; *mail* 103 Maple St., Greenfield, Mass.

VERNON, L. B., (M-7), treasurer, Delaware Seamless Tube Co., Auburn, Pa.

WALSH, W. H., (M-7), foreman, English and Mersick Co.; *mail* 527 Orange St., New Haven, Conn.

WERSCHEID, C. G., (A-6), salesman, Crucible Steel Company of America, St. Louis; *mail* 7406 Richmond Place, Maplewood, Mo.

WHITEHEAD, W. A., (Jr-5), 3040 Warren Ave., Chicago.

WILLIFORD, B. L., (M-5), superintendent, C. L. Best Tractor Co., San Leandro, Calif.

ZAVARINE, I. N., (M-7), instructor, Massachusetts Institute of Technology, Cambridge, Mass.

MAIL RETURNED

WHITE, F. J., Crucible Steel Company of America, 1901 Oliver Building, Pittsburgh.

Items of Interest

THE American Metallurgical Corporation, Boston, have announced the installation of the following furnaces: Blake Manufacturing Company, Springfield, Mass., a large electric furnace for the annealing of brass; Pratt and Whitney Company, Hartford, an electric pot furnace; Seamless Container Company, Hartford, an electric air heating unit; Arrow Electric Company, Hartford, an electric heat treating furnace; Jacobs Manufacturing Company, Hartford, an electric pot furnace; and John Bath and Company, Worcester, Mass., an electric heat treating furnace.

The Oxweld Acetylene Company, Long Island City, Chicago and San Francisco, has just published a new 48-page catalog, illustrating and describing in detail their extensive line of acetylene generators and oxyacetylene welding, cutting, brazing, lead burning, heating and decarbonizing equipment. The book is replete with information useful to the user or prospective user of oxyacetylene apparatus.

A. L. Cramp, formerly chairman of the Indianapolis chapter of the American Society for Steel Treating, and previously connected with the Lafayette Motors Corporation, Indianapolis, Ind., has accepted a position as machine shop general foreman with the Haynes Motor Co., Kokomo, Ind.

Robert J. Anderson has resigned as metallurgical engineer of the U. S. Bureau of Mines, and is now engaged in general consulting engineering practice, specializing in the metallurgy of aluminum. Mr. Anderson may be addressed at post office box 111, Fenway Station, Boston.

The Brown Instrument Company announce the appointment of R. D. Bean as chief engineer.

The Walsh Fire Clay Products Company, St. Louis, have recently published a 150-page book entitled, "Refractory Facts." This booklet gives the elementary principles and essential information about fire-clay products.

N. F. Tisdale, formerly sales metallurgist with the Halcomb Steel Company, Cleveland office, recently accepted a position with the Ladish Drop Forging Company, Cudahy, Wis., as metallurgist in charge of production.

Dr. Francis M. Walters, Jr., for the past two years connected with the U. S. Bureau of Standards in Washington as associate physicist, has been appointed director of the special research bureau of metallurgy, which has just been established by the Carnegie Institute of Technology. Dr. Vsevolod N. Krivobok, metallurgist, has been appointed an assistant. The object of the new department is to apply to metallurgy recent discoveries in physics and chemistry. Work of the bureau will begin early in September.

EMPLOYMENT SERVICE BUREAU

The employment service bureau is for all members of the Society. If you wish a position, your want ad will be printed at a charge of 50c each insertion in two issues of the Transactions.

This service is also for employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published at 50c per insertion in two issues of the Transactions. Fee must accompany copy.

Important Notice

In addressing answers to advertisements on these pages, a stamped envelope containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

POSITIONS WANTED

MACHINIST with knowledge of metallographv desires position. First class inspector with machine experience on machine tools and accurate automatic machine parts. Heat treatment inspection experience on tool steel and case carburized work. New England territory preferred. Address 6-10.

METALLURGIST or Assistant desires position in Philadelphia or New York district. At present employed. Four years shop experience in foundry and cupola control. Three years chemical analysis of ferrous and non-ferrous alloys. Supervision of heat treating, inspection and physical testing. One and one-half years as chemist and moulding foreman in steel foundry. Two years pyrometric and laboratory work on ball bearing steels. Technical graduate Age 28. Single. Address 6-15.

FOREMAN HEAT TREATING PLANT. Graduate in metallography and industrial management desires position in charge of heat treating plant. 12 years' practical experience as hardener on tools, carburizing, heat treating and brazing. 10 years' experience in supervising the erection and demonstration of furnaces for various metallurgical purposes. Address 8-5.

TOOL HARDENER desires position. Familiar with carbonizing and all tool steels. 10 years' experience. Can give first class references. Capable of taking charge of hardening room. Location in or around New York preferred. Address 5-15.

CHEMIST AND TREATER desires position where there is a chance for advancement. Location in Philadelphia or vicinity desired. Reasonable salary. Address 5-25.

CHEMIST AND METALLURGIST desires position. Capable of handling or developing chemical and metallurgical laboratory. Experienced in microscopic examination of steel for controlling heat treating in industrial plant. Familiar with latest forging, annealing and hardening practices and equipment with pyrometric control. Capable of carrying out experimental work to improve product. Prefer Chicago location. Married. Address 7-15.

POSITIONS WANTED

HEAT TREATER desires position. Can give references. Location preferred—Cleveland, Toledo or Detroit. Address 7-5.

POSITIONS OPEN

WANTED graduate chemist with experience in metallography and heat treatment of large sections. Address 6-5.

METALLURGIST skilled in the theory and practice of physical metallurgy. Applicant must have a university training with from three to five years' practical experience in heat treatment and factory control. State age, experience and practical experience. Address 8-15.

WANTED RECENT TECHNICAL GRADUATE for metallurgical research on non-ferrous alloys. Good fundamental training in the principles of metallography required. In replying give education and training, industrial experience, age, religion and nationality, whether married or single, and references. Address 7-10.

WANTED—Tool steel salesman by high grade tool steel mill for work in Chicago and adjacent territory. Salary and commission arrangement. Very fine proposition for high grade man. One who has travelled. Chicago territory preferred. State full experience. Address 8-10.

WANTED

WANTED—Stanton Repeated Impact Testing Machine. Second hand. Advise condition and price. Address 7-20.

WANTED TO BUY—A used Olsen Testing Machine, or similar make, 100,000 to 200,000 capacity. Must be in A-1 condition. Address 7-30.

The United States Civil Service Commission announces the following open competitive examination for the position of assistant examiner.

The examination will be held throughout the country on August 20 and 21. It is to fill vacancies in the Patent Office, Washington, D. C., at an entrance salary of $1,860 a year.

Examination will be given in the following optional subjects: Chemical engineering, civil engineering, electrical engineering, electrochemistry, general chemistry, and mechanical engineering.

The examination will consist of physics, mechanical drawings, technics, the optional subject chosen, mathematics, French and German.

As the Commission has had great difficulty in securing sufficient eligibles for this position, qualified persons are urged to enter this examination.

It is especially desirable to call attention to the educational facilities in Washington, D. C. Two universities conveniently located at the National Capital offer engineering and scientific courses. Credits from any standard college may be transferred to either of these institutions and studies may be pursued in evening classes while students who have received appointments are holding very profitable employments.

Full information and application blanks may be obtained from the United States Civil Service Commission, Washington, D. C., or the secretary of the board of U. S. civil-service examiners at the post office or custom house in any city.

We often hear of the romance of business or of the romance of steel. This romance has certainly been lived in the case of Hi-Tempo metal recently introduced to the general market.

According to the Case Hardening Service Company and the Bell & Gossett Company who are the sponsors of the metal, it was first developed some eight or ten years ago.

A customer needed an extraordinary heat-resisting metal for cyanide pots, and he would pay only a comparatively small price. After a long series of experiments a metal was developed that appeared as though it would do the job.

The customer tried it and reordered from time to time. The metal had no name—simply a formula number. The war, and particularly its aftermath, was responsible for letting the proposition drift along, as the saying goes, while in the meantime the original customers had told others about it until there were quite a respectable number using the metal.

All this time, however, it was being used only for pots and boxes. Early this year it was decided to actively push it. An advertising campaign was begun, telling about the records of the metal, and over night it sprang into national prominence.

But the real romance came when uses other than pots and boxes were developed—now galvanizing boxes, hearth plates, grate bars, etc., are being made from the metal.

And every day still another use is being developed. At least a half dozen large corporations are now trying it out on jobs never before tried. By the time these new jobs become an old story there will be other new ones.

And so the romance of business and the romance of steel lives.

Temperature

With the *F. and F. Optical Pyrometer* the temperature is measured by merely observing the object. It is accurate, simple, substantial and direct-reading.

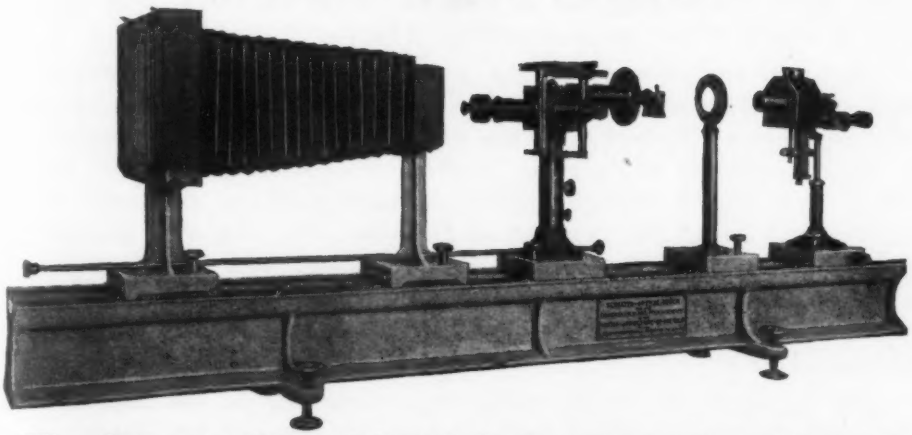
(Write for Booklet)

Hardness

The *S. M. Co. Brinell Machine* is the standard machine for measuring hardness of metals and is used by the leading concerns.

Pressure is applied quickly and uniformly; a special feature prevents leakage of the hydraulic fluid.

Micro-Structure



The *Scimatco Optical* Bench is the advanced outfit used by many of the foremost metallurgical firms for observing and photographing the micro structure of metals.

SCIENTIFIC MATERIALS COMPANY

"Everything for the Laboratory"

PITTSBURGH, PA.

The United States Civil Service Commission announces the following open competitive examination: Associate Mechanical Engineer (Gases).

Applications for the above position will be accepted until August 19. The examination is to fill a vacancy in the office of the Chief of Air Service, War Department, Washington, D. C., and vacancies in position requiring similar qualifications, at an entrance salary of $3,000 a year. Advancement in pay may be made without change in assignment up to $3,600 a year.

The duties of this position, under direction, are to develop improvements and supervise or conduct experimental tests on apparatus for the production, storage, purification and handling of helium, hydrogen and related gases. Applicants must be thoroughly familiar with at least several types of commercial air and liquefaction gas production plants, their operation and their equipment, and must have a knowledge of the purification and separation of gases by the liquefaction method, and the related work as required.

Competitors will be rated upon their education, training, and experience.

Full information and application blanks may be obtained from the United States Civil Service Commission, Washington, D. C., or the secretary of the board of U. S. civil-service examiners at the post office or custom house in any city.

Three important studies in metallurgical research will be undertaken in Pittsburgh during the coming year by the Carnegie Institute of Technology in co-operation with the U. S. Bureau of Mines, says an announcement. The problems, which were selected by an advisory board of steel manufacturers and metallurgical engineers will be investigated as a result of the recent arrangement developed by the Institute and the Bureau of Mines under which definite programs of research studies are to be made each year for the benefit of the metal industries.

To carry on the work in 1924-1925 four college graduates have already been appointed to research fellowships to make the studies. The appointees are announced as Herbert S. Karch, of Pittsburgh, who was graduated from the evening courses at Carnegie Institute of Technology in June of 1924 with a B. S. degree in metallurgical engineering; Ernest L. Bauer, of Butler, Pa., and Joseph M. Campbell of Duquesne, Pa., who were graduated in June of 1924 from Pennsylvania State College, with B. S. degrees in metallurgical engineering; and Wayne L. Cockrell, of Dayton, Ohio, a graduate of 1924 from the University of Cincinnati with a degree of chemical engineer.

The appointments to the fellowships, according to the announcement, were made from applications received from all parts of the country.

Mr. Karch will be assigned to a senior investigator representing the Pittsburgh Station of the U. S. Bureau of Mines, and will study corrosion of metals due to high pressure steam; Messrs. Bauer and Campbell will collaborate with a Bureau of Mines investigator in a study of the atmosphere in openhearth steel making furnaces as affecting refractories. Mr. Cockrell has been assigned to work under the direct supervision of professor Fred Crabtree, head, and associate professor F. F. McIntosh, of the department of metallurgy in the study of the effect of various percentages of phosphorous on the physical properties of low carbon steel.

The metallurgical research work at the Pittsburgh Institution this year

SIMONDS STEEL

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For those users who demand the most
from their finished steel product

PERMANENT MAGNET STEELS
HIGH SPEED
BULLET PROOF STEEL for ARMORED CARS
VALVE STEELS
CHISEL STEELS
CARBON AND ALLOY TOOL STEELS
SPECIAL STEELS

BARS SHEETS BILLETS

SIMONDS SAW and STEEL CO.
STEEL MILLS
Lockport, N. Y.

doubtless will be watched with considerable interest by Pittsburgh steel industries, as Dr. D. A. Lyon, chief metallurgist of the U. S. Bureau of Mines, has assured president Thomas S. Baker that if sufficient encouragement was offered, the Bureau would concentrate its metallurgical work on iron and steel at the Pittsburgh station. The preliminary negotiations preparatory to the final agreement apparently have aroused much enthusiasm in the Pittsburgh district, whose iron and steel manufacturers see an unusual opportunity for the metal industries in the event that co-operative research in metallurgy is concentrated in the district. The arrangements have already received the financial support of some of the steel companies represented on the advisory board.

The metallurgical research work, it is expected, will be conducted similarly to the co-operative program now used by Carnegie Tech, the Bureau of Mines, and an advisory board of coal operators and mining engineers, in connection with research in coal mining prbolems.

Harry F. Stimpson, having completed a very successful thirty-year career in the steel business, and desiring to devote more time to the development of his large industrial real estate holdings, has resigned as president and general manager of Wheelock, Lovejoy and Co., Inc. Mr. Stimpson still retains a substantial investment in the company, but withdraws from active participation in its affairs. A. Oram Fulton, who has been intimately associated with Mr. Stimpson for the past fifteen years, and has been vice-president of the company since its incorporation, has been elected president and general manager. F. H. Lovejoy, whose training and experience in the business of the company, admirably fit him for the duties of his new office, has been elected vice-president.

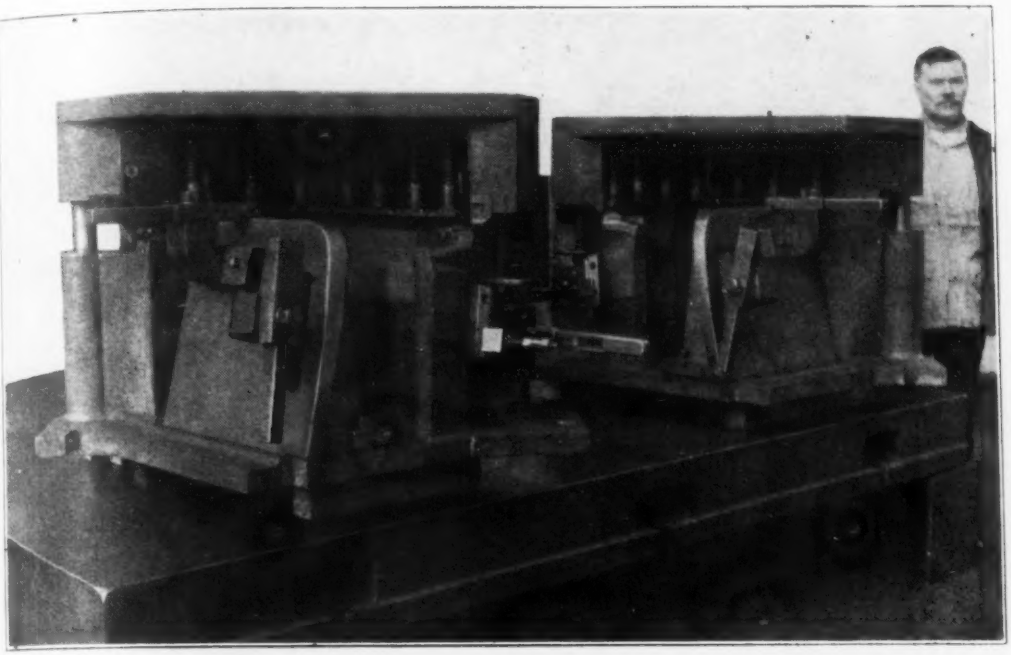
Ethel H. Bailey, formerly with L. W. F. Engineering Company, 82 McDougal Street, New York City, in charge of material testing, has accepted a position as engineer in the research department of the Society of Automotive Engineers, 29 West 39th Street, New York City.

Word has been received that Dr. Albert Sauveur, Harvard University, Cambridge, Mass., on June 5th was awarded the degree of "Docteur, 'honoris causa'," by the University of Grenoble in France. He has also received the cross of "Officer de l'ordre de Leopold" (Belgium).

A simplified metallographic equipment for general routine inspections has been introduced by the Bausch & Lomb Optical Company, of Rochester, N. Y. Such inspections seldom, if ever, require magnifications above 200 diameters, and hence do not require the expensive parts which are so necessary in research outfits.

This simplified metallographic equipment is a very compact unit, with all of the parts mounted on one base, and with the light source in fixed position. The equipment includes an inverted microscope, camera and special ribbon filament illuminant. It is easy to operate, easily portable and especially suited for low power work. It gives magnifications varying from 64 to 210 times.

MIDVALE



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AUTOMOBILE BODY BLANKING AND FORMING DIES

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MIDVALE EXTRA GRADE VIII
TOOL STEEL

Write for Pamphlet—Just off the Press

THE MIDVALE COMPANY
NICETOWN, PHILADELPHIA

District Offices:

NEW YORK
PITTSBURGH
WASHINGTON
CLEVELAND
CHICAGO
SAN FRANCISCO

A practical cleaner and grader for carburizing compound is being manufactured by the Brown Lynch Scott Company of Monmouth, Illinois. This machine is entirely enclosed with sheet steel, making it practically dust proof. It will quickly pay for itself in the saving of compound and time, beside eliminating the disagreeable hand sifting. This mechanism will be exhibited at the Boston convention of the A. S. S. T.

We regret to announce that due to an oversight in proof reading, the address of the Griscom-Russell Company of New York Cty, in their advertisement appearing in the July Transactions was given as 79 West Street, in place of 97 West Street. It is possible that mail addressed to them at the incorrect address has gone astray and we would suggest that readers desiring a copy of their free book on Proper Cooling Temperatures in Heat Treating Operations write to them at 97 West Street.

To commemorate the pioneer aeronautical achievements of the Wright Brothers, the Dayton Section, Society of Automotive Engineers, will award a medal annually for the most meritorious contribution to aeronautical science reported to them during the year.

The contribution to, or discovery in aeronautical science and art may include advances in aerodynamics, development in construction of airplanes, power plants for same, accessories which increase their efficiency or reliability, such as fuel systems control mechanisms, aerial navigation instruments, etc. Improvements for military application, ordnance, aerial photography, etc., are ineligible competition for this award. The prize will be awarded for contributions designed to stimulate increased non-military use of heavier-than-air craft.

Competition for this prize is open to any individual citizen or group of not more than two individual citizens of any country excepting that S. A. E. National Officers and Dayton Section S. A. E. Officers, contest committee members, and award committee members are ineligible.

The award will be for intrinsic merit of achievement rather than merit of the paper describing it. Flight tests are desirable, and papers including complete reports of them, under proper conditions in the presence of unbiased observers is advantageous to the competitor. Flight tests will not be absolutely insisted upon as these might be financially impossible for individuals, though the proposed improvement would be clearly evident to a competent award committee.

Papers should be plainly labeled with author's name and address and forwarded to the Wright Brothers' Medal Committee, Dayton Section S. A. E., care of Engineers' Club of Dayton, Dayton, Ohio.

The Award Committee will be appointed annually by the Section Contest Committee:

The paper describing the achievement for which the medal is awarded shall be presented originally before the Dayton Section, S. A. E., either by the prize winner, or if this proves impracticable, by some member of the local section appointed by its officers.

The award for 1924 shall be based on papers received up to December 31st, 1924, and shall be announced as soon as all papers and data therein can be checked. The Dayton Section S. A. E. reserves the right to withhold any award if the Award Committee finds no paper submitted of proper standard.